CALFED BAY-DELTA PROGRAM

CALFED SCIENCE FELLOWS PROGRAM

In cooperation with the

California Sea Grant College Program

FELLOWSHIP APPLICATION COVER PAGE

APPLICANT TYPE [x] Postdoctoral Researcher [ ] Ph.D. Graduate Student

PROJECT NUMBER

PROJECT TITLE CALFED Fellows Program

FINANCIAL SUMMARY

First Year CALFED Funds Requested:	$82,475
Total CALFED Funds Requested:	$164,931
Duration:	2 years
Proposed Start/Completion Dates:	1/15/2009-1/14/2011

APPROVAL SIGNATURES

FELLOW:

Name: K. Ali Ger
Position/Title: Postdoctoral fellow
Department: Romberg Tiburon Center
Institution: San Francisco State University
Address: 1600 Holloway Ave.
City, State & Zip: San Francisco, CA 94132
Telephone: 530-752-1967
Fax:
E-mail: kager@ucdavis.edu

MENTOR/PRINCIPAL INVESTIGATOR:

Name: Wim Kimmerer
Position/Title: Senior Research Scientist
Department: Romberg Tiburon Center
Institution: San Francisco State University
Address: 1600 Holloway Ave.
City, State & Zip: San Francisco, CA 94132
Telephone: 415-338-3515
Fax:
E-mail: kimmerer@sfsu.edu

AUTHORIZED INSTITUTIONAL REPRESENTATIVE:

Name: Dr. Kenneth Paap
Position/Title: Associate Vice President of Research and Sponsored Programs
Department: Office of Research and Sponsored Programs
Institution: San Francisco State University
Address: 1600 Holloway Ave.
City, State & Zip: San Francisco, CA 94132
Telephone: 415-338-7091
Fax: 415-338-0531
E-mail: kenp@sfsu.edu

Will animal subjects be used? [ ] Yes [x] No
APPROVAL DATE: PROTOCOL #: PENDING:

Does this application involve any recombinant DNA technology or research? [ ] Yes [x] No

Proposed Research **K. Ali Ger**

Trophic Impacts of *Microcystis* on the crustacean zooplankton community of the Delta

Introduction

The recent decline in the pelagic foodweb of the upper San Francisco Estuary (SFE) has caused widespread concern in management agencies and the public. Abundances of several pelagic fish species have declined to historically low levels, and the apparent slide to extinction of the Delta smelt, along with the consideration of longfin smelt for listing, raise serious worries that the entire pelagic ecosystem may be affected. This broad decline across the foodweb has led to new ecological studies on multiple stressors and the consideration of several synergistic processes such as hydrographic changes, water quality, species introductions, food limitation, habitat quality and connectivity, and fisheries ecology (Sommer et al 2007). An ambitious multiagency research group has been studying the potential causes of the decline (POD Management Team 2007).

The conceptual model used to investigate the potential causes of decline has four main components; 1) effect of previous abundance on juvenile fish production; 2) effects of habitat and water quality on estuarine species; 3) top-down effects due to predation and entrainment; and 4) bottom-up effects, essentially food limitation (Sommer at al 2007).

Seasonal blooms of the toxic colonial cyanobacteria *Microcystis aeruginosa* may have played a role in the decline in pelagic fish through changes in water quality and trophic interactions (POD Management Team 2007). *Microcystis* could be having an impact on the pelagic foodweb through its toxicity (essentially a water quality effect) or because it may be an inferior food for zooplankton (resulting in food limitation), though actual impacts are unknown. *Microcystis* likely reduces phytoplankton food quality and thereby habitat quality for preferred pelagic fish prey such as *Pseudidiaptomus forbesi*.

Elsewhere, *Microcystis* blooms have caused zooplankton community shifts to smaller and more tolerant species in eutrophic lakes, rivers, and upper estuaries globally (Chorus and Bartram 1999, Paerl 1988). Impacts to zooplankton are species-specific and due to a combination of toxicity, nutritional deficiency, and consumption-resistant morphology. The cumulative response of the zooplankton community depends on the dynamics of each system. A large body of research indicates that trophic impacts due to interference with grazing by herbivorous zooplankton can be substantial (Christoffersen 1996, Chorus and Bartram 1999, Zurawell et al 2005). Thus, there is good reason to believe that *Microcystis* blooms in the upper SFE could exacerbate food limitation and declines in the abundance of zooplankton that are prey to pelagic fish.

Microcystis blooms have been a regular feature of the Delta for almost a decade, yet there is virtually no information on their impacts on the pelagic foodweb. Blooms of *Microcystis* were initially observed in localized surface scums in the late 1990's , though the species was recorded previously in non-bloom forming quantities (Lehman et al 2008, Bay Delta Tributaries Project). In the last 9 years, annual blooms have extended over wide regions of the Delta, in salinities of 0.1-18, beginning in June and reaching their peak between September and October (Lehman et al 2008). The geographic range of the blooms has been expanding, implying permanent establishment in the SFE (POD Management Team 2007). Although *Microcystis* was previously most abundant in low-flow waters of the Central Delta, the most recent monitoring from 2007 suggests that its abundance in Antioch has become comparable to that in the Central Delta (POD Management Team 2007, personal observation). *Microcystis* now occurs seasonally from Suisun Bay to the freshwater habitat of rivers feeding the Delta, with greatest abundance in the Central-South Delta and more recently at the confluence of the Sacramento and San Joaquin Rivers (Lehman 2005, POD Management Team 2007).

Here I propose to investigate the contribution of *Microcystis* to the decline in pelagic organisms through a careful study of food limitation, habitat quality, and trophic interactions with zooplankton. This work will build on my current graduate research investigating the toxic and nutritional impacts of Microcystis on copepods.

I will quantify and model routes of exposure of SFE zooplankton to *Microcystis* using a combination of field and laboratory experiments, apply novel molecular methods for measuring in-situ ingestion rates, and collect information on how *Microcystis* changes species-specific survival and consequently the community composition of SFE zooplankton. The decline of the pelagic ecosystem to historically low levels places *Microcystis* as a potentially significant strain on the planktonic foodweb, and the extent of this strain is ripe for investigation.

Background

Cyanobacterial blooms are a key issue in aquatic management for a variety of reasons that stem from toxin exposure to the foodweb and changes in the trophic transfer of carbon (Chorus and Bartram, 1999, Hansson et al, 2007). Blooms of toxic cyanobacteria now globally threaten water quality, human uses such as water consumption and fishing, and fundamental ecological functions (Anderson and Garrison 1997, Paerl 1988, Stahl-Delblanco et al. 2003, Graneli and Turner 2006). *Microcystis aeruginosa*, one of the most common species of freshwater cyanobacteria worldwide, forms colonies, and is dominant in many eutrophic and hyper-eutrophic waters including upper reaches of estuaries (Paerl 1988, Christoffersen 1996). In recent years there has been an increase in the abundance and distribution of toxic *Microcystis* blooms in the landward portion of the San Francisco Estuary (SFE), with unknown impacts to the foodweb (Lehman et al 2008).

Microcystis blooms occur under environmental conditions that include high nutrients, low dissolved carbon, stratified water column, and warm water temperatures. Given the current state of the SFE and the life history of *Microcystis*, these blooms are likely a permanent seasonal trait (POD Management Team 2007). Monitoring and predicting the impacts of such blooms is of fundamental interest to aquatic research and management, and its potential impact on food limitation in the SFE cannot be ignored (Ouelette and Wilham 2003, Chorus and Bartram 1999).

Microcystis is known to shift zooplankton community composition towards smaller species, or those able to graze on it directly (Lampert 1987, Chorus and Bartam 1999, Nadini 2003, Graneli and Turner 2006). However, the majority of the information pertaining to *Microcystis* is based on laboratory studies using *Daphnia* spp. as the test organism, while only a small fraction is based on copepods (reviewed in Wilson et al 2006). Copepods are the dominant zooplankton in the SFE so information on copepod – *Microcystis* interactions will benefit management of the SFE as well as other estuaries (POD Management Team 2007, Wilson et al 2006). Mechanistic evidence from laboratory studies shows that *Microcystis* typically suppresses feeding in large zooplankton grazers because of its colonial morphology, toxic properties, and nutritional deficiency (Wilson et al 2006, Lampert 1987, Christoffersen 1996, DeMott and Moxter 1991). However, the role of *Microcystis* on trophic shifts in zooplankton communities is not clear because it is difficult to observe in the field and species-specific differences cause contradictory effects (Kumar 2003, Ghaouani et al 2003, Kirk and Gilbert 1992).

Possible role of *Microcystis* in the food limitation of pelagic fish

Increasing blooms of the cyanobacteria *Microcystis aeruginosa* in the freshwater and low salinity zones of the SFE come at a time of historically low abundances of both calanoid copepods and nutritious phytoplankton, raising concern for further depletion of high quality fish food (Mueller-Solger et al 2002, Lehman et al 2005, POD Management Team 2007, Sommer et al 2007). To our knowledge, there is no

information regarding the mechanisms by which *Microcystis* changes zooplankton community structure or the routes of exposure in the SFE, but it has the potential to reduce habitat quality for copepods.

High abundances of consumption-resistant algae such as *Microcystis* may impact the foodweb in three ways, 1) Reduce the quality of total phytoplankton biomass; 2) increase foodchain length by shifting zooplankton grazing to microbial sources, reducing overall zooplankton productivity; 3) change the zooplankton community composition by favoring smaller, non-herbivorous copepods such as cyclopoids, rotifers, and protozoans (Kirk and Gilbert 1992, Smith and Gilbert 1995, Ghadouani 2003, DeMott and Tessier 2002). The trophic response of the pelagic foodweb to increased cyanobacterial primary production is governed by the identity of zooplankton and their feeding ecology (Stibor et al 2004, Lampert 1987). It is necessary to quantify in-situ grazing rates and feeding ecology of zooplankton to understand the dynamics of *Microcystis* impacts to the foodweb.

Why copepods? Implications of the Delta's shifting copepod community

Copepods dominate metazoan/mesozooplankton in the Delta and are the main food source for small pelagic fish (Mueller Solger et al 2006, Kimmerer 2004). Calanoid copepods that can consume phytoplankton (*E. affinis* and *P. forbesi*) form shorter and more productive food chains that fuel the pelagic ecosystem. A decline in such copepods may signal alternative trophic pathways, in part due to *Microcystis* blooms, shifting the zooplankton towards non-herbivorous species. Long term monitoring indicates significant shifts in the copepod community (POD Management Team 2007), including a more variable abundance in all species, a decrease in the once common calanoid *E. affinis*, its replacement with *P. forbesi* as in the diets of fish, and increased abundances of non-herbivorous copepods including cyclopoids and *Acartiella*. The SFE's previously abundant calanoids *P. forbesi* and *E. affinis* have been in decline, with potentially severe consequences on pelagic fish (Sommer at al 2007).

Pre-1980's monitoring shows that *E. affinis* was dominant year round, and other copepods were not so abundant. Peaks of *E. affinis* abundance are now limited to spring. *P. forbesi* takes over in early summer, and shares habitat with the predatory *Acartiella sinensis* and the small cyclopoid *Limnoithona* (Kimmerer 2004, Bouley and Kimmerer 2006). These changes, the results of introductions from East Asian estuaries, have effectively reshaped the zooplankton community, with likely changes in the trophic structure of the foodweb.

Copepod feeding ecology, food limitation, and *Microcystis*

Copepods feed selectively on a wide variety of food particles ranging from the smallest phytoplankton to protozoans, detritus, and larger prey including other copepods (Nejstgaard et al 2008, DeMott and Felix 1991, Kumar 2003, Koski et al 1999). Mechanisms behind food selection are species-specific and include biochemical and mechanical cues as well as the mode of feeding, i.e. raptorial versus suspension feeding (Bouley and Kimmerer 2006, Gasparani and Castelt 1997). The SFE has always had relatively low rates of primary production and phytoplankton abundance, probably because of the high concentration of suspended sediments (Jassby et al 2002, Kimmerer 2004). Together, these attributes are known to select for omnivorous zooplankton that have selective ability to capture prey (Gasparini et al 1999). Omnivorous copepod feed on both microbial and autotrophic food chains, though species-specific adaptation to a certain diet is important (DeMott 1995, Kumar 2003, Panosso et al 2003).

Suspension-feeding calanoid copepods such as *E. affinis* can select particles following predictions of an optimal diet model, i.e. to maximize energy input per unit of expenditure (DeMott and Moxter 1991, Gasparani and Castelt 1997). Calanoid copepods have been shown to successfully select against *Microcystis* (DeMott and Moxter 1991, Koski et al 1999). The strength of selection depends on the feeding adaptation of species, abundance of nutritious food particles, and suspended sediment (DeMott

and Moxter 1991, Gasparini and Castel 1997). As long as adequate nutritious particles are available, selective feeding is an adaptation to avoid harmful or non-nutritious particles. Strong feeding selection is an advantage to copepods, as they are able to switch between different food sources to maximize benefit from a variable resource. Overall, copepod response to changes in food quality, such as an increase in *Microcystis*, will be a function of the species-specific adaptations for ingesting phytoplankton versus protozoans (DeMott and Moxter 1991, Kumar 2003)

The long-term decline in phytoplankton abundance in the Delta raises concern that there might not be enough high quality food for *P. forbesi* and *E. affinis*, which are the dominant prey species for larval fish (Mueller-Solger et al 2006, POD Management Team 2007, Sommer 2007). Both are suspension-feeding copepods that can survive and reproduce on a sole diet of nutritious phytoplankton, but probably feed opportunistically on protozoans and even detritus in the Delta (Bouley and Kimmerer 2006, Mueller Solger et al 2006 , Gasparini et al 1999). Feeding experiments show that *P. forbesi* selects high quality phytoplankton such as diatoms over microbial food (Bouley and Kimmerer 2006, Mueller Solger et al 2006). *E. affinis* selects smaller food particles under high suspended sediments, but ingests nutritious phytoplankton under less turbidity (Gasparini and Castel 1997). Additionally, laboratory tests indicate that *P. forbesi* has higher survival when fed *Microcystis* in a mixed diet with other phytoplankton, compared to *E. affinis* (Ger et al, in prep). *Microcystis* can exacerbate food limitation for copepods adapted to phytoplankton diets. My current doctoral work investigates the acute and chronic toxicity, as well as the dietary effects of *Microcystis* in a mixed diet on the copepods *P. forbesi* and *E. affinis* under controlled laboratory conditions. We found that survival in these copepods is a function of *Microcystis* ratio in the diet, higher mortality occurred for non-toxic *Microcystis*, and mortality ceased after 4-7 days for toxic *Microcystis*, provided in a mixture with high quality food. Results show that impacts of *Microcystis* on *P. forbesi* depend on available high quality phytoplankton food sources (Ger et al, in prep).

On the other hand, the dominant, small cyclopoid *Limnoithona tetraspina* shows a clear adaptation for microbial prey, especially heterotrophic ciliates. While there is probably some prey overlap between *L. tetraspina* with *P. forbesi* and *E. affinis*, the distinct diets and feeding adaptations of these copepods place them in somewhat separate foodchains (Bouley and Kimmerer 2006). All three copepods are likely limited by food supply (POD Management Team 2007). Blooms of *Microcystis* may shift copepod grazing to microbial food, and select for species such as *Limnoithona* or *Acartiella*. It has been suggested that *Limnoithona* is able to avoid predation by Delta smelt due to its non-motile behavour, and thus may be a high-cost food for pelagic fish (Bouley and Kimmerer 2006). *Microcystis* is unlikely to interfere with the feeding of such species.

qPCR as a new method for quantifying copepod feeding and trophic interactions

The emergence of ecosystem-based management, coupled with increased awareness of human impacts on ecosystems, has driven the need for organismal data that have greater resolution and accuracy (Hoffmann and Gaines 2008). Recent advances in DNA based biomarkers for the rapid and precise diagnosis of *Microcystis* abundance, toxicity, and species-specific foodweb interactions with zooplankton are a response to this need (Ouellette and Wilhelm 2003, Nejstgaard 2008). Given the complexity of multiple stressors and a constantly changing environment, managers will increasingly rely on DNA-based biomarkers to monitor trophic dynamics and assess ecosystem function (Hoffmann and Gaines 2008). The proposed project will apply this emerging method to track the species specific feeding ecology and response of the SFE's zooplankton community to *Microcystis*.

Recent improvements in molecular methods such as quantitative PCR provide rapid and sensitive diagnosis for the identification of copepod diets based on prey DNA sequences, including *Microcystis* (Nejstgaard et al 2008, Oberholster et al 2008). There are several ways to quantify copepod ingestion and

prey selection such as isotopic and microscopic in-vitro methods, and fluorescence based in situ estimates of gut contents. However each method has its limitations due to bottle effects, time constraints, biases due to differential pigment degradation, and limitation to pigmented prey. Advances in the use of DNA based biomarkers imply that prey DNA can be used as a quantitative measure of feeding selection and ingestion rates in copepods.

Nejstgaard et al. (2008) found that the 18s DNA target gene of the algal prey in a marine copepod can be used as a marker for algal prey. The relationship between PCR detection and prey gut content becomes increasingly quantitative when the ambient prey gene concentration is known. The breakdown of prey DNA is the main reason preventing this method of being fully quantitative and independent of calibrations. Still, because DNA is a chemically stable molecule in living cells, the breakdown of DNA in guts should be less than that of chemically unstable pigments, which are commonly used to quantify ingestion. Another study successfully used qPCR to amplify target *Microcystis* genes in the field from cladocerans (Oberholster et al 2008). That study used the *mcy* gene cluster, which encodes microcystin synthetase, as a molecular marker for ingestion by *Daphnia. magna*. Gut content analysis revealed that majority of the *Microcystis* cells were still intact, implying minimal loss of DNA. Using the *mcy* gene cluster also enables the detection and quantification of the microcystin production of the specific *Microcystis* strain ingested. This is the only method that can quantify in-situ ingestion of different *Microcystis* strains (Oberholster et al 2008).

Development of calibrated qPCR ingestion measurements such as the work proposed here will provide the most accurate measure of in-situ measurement of ingestion, without the costs and limitations of other methods (Nejstgaard et al 2008). Although only recently used to measure in-situ zooplankton ingestion and prey selection, PCR-based molecular tools for ecologists are rapidly evolving and new applications of such techniques will improve our knowledge of the trophic interactions between *Microcystis* and zooplankton. Developing a PCR-based method for quantifying ingestion will also benefit routine monitoring of zooplankton during *Microcystis* blooms to determine the extent and fate of *Microcystis* ingestion in zooplankton.

The objective of the proposed project is to 1) develop a calibrated qPCR based method to quantify in-situ *Microcystis* ingestion using target zooplankton species, 2) apply this method in field mesocosm and laboratory feeding experiments to quantify in-situ ingestion of *Microcystis* and subsequent changes in zooplankton survival and community composition, and 3) compile results to determine impacts to zooplankton community composition. This will help to identify management alternatives specific to the Delta through a comparison to other affected estuaries around the world. The objectives will answer the following questions:

- How useful is qPCR as a monitoring tool for *Microcystis* ingestion?
- What are the trophic dynamics by which *Microcystis* changes the zooplankton community composition?
- Does *Microcystis* reduce the habitat quality of preferred fish prey such as *P. forbesi*?
- What zooplankton species benefit and suffer from increased *Microcystis*?
- Are there predictable changes in estuarine foodwebs due to *Microcystis* blooms?
- What is the contribution of *Microcystis* to the food limitation of pelagic fish?

Approach

We will test the hypothesis that *Microcystis* abundance causes predictable shifts in the SFE's zooplankton community with a series of laboratory experiments and field measurement of in-situ ingestion rates. DNA-based markers will be applied using quantitative PCR to estimate ingestion rates under laboratory conditions with the target copepod, ***P. forbesi***, and calibrated using established techniques such as radiolabeling. A combination of these techniques will be used to quantify *in-situ* ingestion rates of zooplankton in the field and in laboratory under controlled conditions. Our aim is to determine a potential relationship between *Microcystis* abundance and the change in zooplankton species composition based on species-specific ingestion and survival rates. Results can be used to model the zooplankton community response (survival, species composition) to various scenarios of *Microcystis* abundance (biomass, toxicity, duration) to understand the role that *Microcystis* plays in food limitation of pelagic fish in the SFE.

Culturing

A large quantity of ***P. forbesi*** will be used in the experiments. Small (4L beakers) batch cultures as well as a large mass culture (50 – 100 L) will be maintained to ensure enough test organisms. Cultures will be started from those existing at UC Davis, in collaboration with Dr Swee Teh's lab, and supplemented periodically with copepods from the field. The batch cultures will serve as backup stock to insure against possible loss or degradation of the large culture. Copepods will be fed a mixture of highly nutritious commercially available algal diet (Instant Algae, Reed Mariculture). Cultures will be kept at 24 ^{0}C and 5.0 salinity, and water will be changed regularly to minimize accumulation of ammonia and bacteria. Constant aeration will keep food particles suspended. Copepod density will be monitored regularly and cultures will be diluted as necessary to maintain copepod density below 300/L. Culturing medium and feeding will follow the current method I use (Ger et al, in prep). Only healthy, active late stage juveniles and adults will be chosen for ingestion experiments.

Microcystis cultures will be maintained in a separate room under light- and temperature-controlled conditions. Various strains of *Microcystis* will be obtained from the University of Texas Culture Collection (UTEX), including strains that do not produce microcystin (MC) toxins (UTEX 2386), which will be used as an additional control for *Microcystis* MC content during the ingestion study. Axenic batch cultures will be maintained in 500 ml glass flasks using autoclaved equipment and air filters to prevent contamination. A modified ASM-1 medium will be used under a low light intensity and photoperiod of 16L: 8D at 25^{o} C (Reynolds and Jaworski 1978). We will establish protocols to ensure that cultures of copepods and *Microcystis* remain clean. Specific areas and equipment will be designated for each culture to prevent cross-contamination.

Development of qPCR for in-situ ingestion rates

We will use commercially available primers for use in a rapid and specific PCR test to detect the presence of cyanobacteria, *Microcystis* (MC+ and MC- strains), and toxic *Microcystis* (MC+ only) based on the toxin genes microcystin peptide synthetase B (*mcy*B) and microcystin polyketide synthase D *(mcy*D) (Ouelette et al. 2006). The *mcy* gene cluster can be used as a molecular marker for detection and quantification of *Microcystis*, both in water samples as well as zooplankton guts (Oberholster et al 2006, Ouellette and Wilhelm 2003). Gene copy numbers of cyanobacteria - specific 16S rDNA, *Microcystis* - specific 16S rDNA, and the *mcy* gene cluster will be used to calculate abundance of cells carrying these genes. Fragments of the 16S rDNA gene regions will be amplified, the amplicons cloned, and the plasmids sequenced to design primers for use in a real-time quantitative PCR (qPCR) to estimate the abundance of toxic *Microcystis* in the sample based on the *mcy*D gene (Rinta-Kanto et al 2005, Ouellette and Wilhelm 2003). Probes will be designed following the specifications of Applied BioSciences (Foster

City, CA), and probe specificity will be tested on various *Microcystis* strains before the probes are used for field samples. We will collaborate with Dr Swee Teh and Dr Dolores Baxa from UC Davis to develop and apply this method for quantifying in-situ zooplankton ingestion of *Microcystis*. Dr. Baxa has been developing the use of qPCR and successfully applied it for quantifying gene copy numbers of field *Microcystis* samples. We will work together to further develop this method for use in ingestion studies. Initial development will take place in Dr. Teh's laboratory at UC Davis, though the PCR laboratory at the Romberg Tiburon Center will also be available.

Laboratory ingestion and calibration:

Copepods will be fed *Microcystis* and collected for qPCR analysis as described above. A factorial design of three diet concentrations for at least two different (MC+ and MC-) strains of *Microcystyis* (25%, 50% and 100% *Microcystis* diet by carbon, bringing the total food to 500 $\mu gC.L^{-1}.day^{-1}$ using Instant Algae) with three feeding periods (1, 2, and 6 hours) will be used to allow adequate time for acclimation of copepods to the diet. Copepods will be starved 2 hours prior to experiment to allow gut evacuation. There will be three replicates per treatment, and each replicate will consist of 15 copepods in a 1 L glass beaker. Controls will be fed with the maintenance diet and include a starved control to validate methods (0%, 25%, 50%, and 100% of 500 $\mu gC.L^{-1}.day^{-1}$ Instant Algae diet). From each replicate, two groups of 5 copepods will be randomly selected, rinsed rapidly with deionized water to ensure complete removal of *Microcystis* from the water and exterior of copepods, and placed in a 1.5 ml plastic vial for PCR analysis.

In a separate section of the laboratory authorized for the use of radioactive substances, radiolabeled ^{14}C *Microcystis* will be fed to copepods as an independent measure of ingestion. Rinsed copepods will be filtered or collected in scintillation vials (in groups of 20-30/replicate) and stored for analysis by liquid scintillation (Hargis 1977, Rohrlack 1999). 250 ml of exponentially growing *Microcystis* will be spiked with 1 ml of 22 $\mu Ci\ H^{14}CO_3$ solution, and incubated for 24 hours. This spiked culture will be then fed to the copepods following the same experimental design described for incubation for qPCR. We will calculate the copepod ingestion rate (I) based on the ratio of activity per cell of *Microcystis* and activity per copepod according to the equation below (modified from Hargis 1977). We will also confirm *Microcystis* ingestion using epifluorescence microscopy.

$$I\ [cells.(copepod.hour)^{-1}] = (^{14}C\ ml.\ ^{14}C\ copepod^{-1})\ \times (cells.ml^{-1}) \times (exposure\ hours)^{-1}$$

The relationship between the two ingestion rates (radiolabeled versus qPCR) will give a calibration curve that can be used to estimate ingestion rates from qPCR data taken on copepods collected in the field (Oberholster et al 2006, Nejstgaard et al 2008).

Field collection of zooplankton and Microcystis: in-situ ingestion

Both zooplankton and *Microcystis* will be collected from the same site, with measures taken to minimize the release of toxins from damaged *Microcystis* to zooplankton during the tow. *Microcystis* is generally patchy in its distribution, forming aggregated scums due to wind and wave action. We will take advantage of this patchy distribution and collect zooplankton where *Microcystis* is minimal, and within the same general site, and collect *Microcystis* where it is most dense.

Zooplankton will be collected from various sites in the SFE including Antioch and Suisun Bay, before, during, and after the *Microcystis* bloom to provide a range of conditions. Collection will be done from boat and shore, from the surface layer, using a standard 147μm mesh net equipped with a flow meter. We will fill several previously cleaned 20 L carboys with ambient surface water from the same site, and dilute concentrated zooplankton in the carboys. *Microcystis* will be collected and concentrated using a zooplankton net tow from the surface, and stored in additional carboys until arrival at the RTC for

analysis. Temperature, salinity, and standard water quality parameters will be recorded for each site. We will make sure that the zooplankton and *Microcystis* tows, as well as the water collected have similar physical properties including salinity.

Zooplankton in carboys will be brought to RTC within two hours of each collection and separated into species, rinsed with filtered surface water from the same site and immediately frozen in liquid nitrogen to prevent the loss of gut contents. Specific zooplankton included in analysis will be *P. forbesi*, E. *affinis*, *A. sinensis*, *L. tetraspina*, as well as other copepods and cladocera if time permits. For each species, 5 adults will be placed in a 1.5 ml vial, and frozen immediately upon separation for PCR analysis of target *Microcystis* genes. The *Microcystis* abundance (μg C/L), water quality (dissolved oxygen, temperature, salinity, pH, conductivity), total chlorophyll, and zooplankton species composition will be determined for each site and sampling event. Collections site will be selected based on *Microcystis* and zooplankton abundance, and will likely include Antioch, and possibly Mildred Island, locations of the most dense blooms.

Mesocosm experiments: survival, ingestion, change in species composition

Using the carboys from above, we will evaluate the impact of *Microcystis* abundance on in-situ grazing rates, survival, and change in species composition (abundance of species *x*/total species abundance) of zooplankton. To do this, we will set up 20 L mesocosms in a light and temperature controlled chamber, and vary initial *Microcystis* biomass. There will be three treatments (low, ambient, and high *Microcystis*), and two replicates. The whole procedure will be repeated at least once more to allow temporal replication. Each container will be sampled every 3 hours during the first 12 hours, and then once every 24 hours for three days.

This setup will be repeated in the spring, prior to bloom formation. As there will be no *Microcystis* naturally, we will add known amounts (based on summer abundances) of cultured *Microcystis* to run the experiments in the same design explained above. This will measure the potential impact of *Microcystis* on the spring zooplankton community.

In the laboratory, *Microcystis* will be rinsed in filtered surface water, filled into graduated cylinders, and allowed to separate from foreign particles by letting it remain in filtered surface water. By its positively buoyant nature, *Microcystis* will concentrate at the surface and stabilize its biovolume after 30 minutes, making it possible to modify initial abundances. Once it stabilizes, *Microcystis* biomass for the mesocosm experiment will be manipulated using the biovolume of colonies. The relationship between *Micocystis* biomass and biovolume will be quantified by using previously established conversions. Biomass per volume will be measured in μg C (with a GC).

At least three samples of zooplankton (5 animals each) will be taken for each replicate and feeding period, zooplankton samples frozen immediately to minimize loss of gut contents, and later isolated to species as described above to quantify *Microcystis* ingestion, change in abundance over time (survival), and change in overall zooplankton community. Experiments will be terminated after three days and samples will be stored at -80^0C till analysis. A continuously circulating system will be maintained by using available supplies such as a motorized paddle at the bottom of each mesocosm to minimize settling of sediments.

Data analysis and modeling

Results will be analyzed using standard statistical techniques such as ANOVA, with graphical analysis used to ensure data meet the criteria for each technique used. Calibration between different ingestion measurements will be analyzed using standard regression methods. Results from the above experiments will be combined to develop simple population dynamics models of zooplankton based on *Microcystis*

abundance, initial zooplankton composition, and ingestion. These models will be used to predict the impact of *Microcystis* on the pelagic foodweb of the SFE, focusing on zooplankton resources for fish for which diet and ingestion rate information are becoming available. Finally, the models will be combined with a literature review from comparable estuaries with *Microcystis* blooms to try to identify long-term solutions to manage *Microcystis* in a changing estuary.

Output/Anticipated Benefits and Products

This project will provide a quantitative diagnosis of the mechanisms by which *Microcystis* impacts the SFE's pelagic foodweb. It will show the degree of impact to the food quantity and quality for zooplankton, and provide predictions for the response of the foodweb to future *Microcystis* blooms. Studies that focus on the trophic interactions at the base of the foodweb are critical for management of higher trophic levels such as fish. This project benefits the CALFED priority areas as it explores how zooplankton and the primary food resource to larval pelagic fish respond to the expanding blooms of *Microcystis*.

Connectivity and variation in food quality among habitats of the SFE is now emerging as an important research area as more information becomes available. The POD Management team compiled evidence for bottom-up food limitation as an important factor for the decline in pelagic organisms, yet finer scale observations point to new processes that regulate the system's response to changes. It remains unclear why *P. forbesi* has declined in the Western Delta and Suisun Bay but not in the Southern Delta (POD Management Team 2007). Total phytoplankton biomass (chlorophyll) did not decline in these regions between 1995-2004, but *P. forbesi* abundance showed different trends. Such differences raise questions about phytoplankton food quality and the importance of source populations for key copepods such as *P. forbesi*.

Food quality for pelagic zooplankton is determined by the relative contribution of various phytoplankton and microbial species to the total particle pool available to primary grazers (POD Management Team 2007). Areas rich in high quality phytoplankton particles (such as the southern Delta) may create critical source populations of fish prey including *P. forbesi*. *Microcystis* can reduce the amount of high quality phytoplankton ingested by *P. forbesi*, and threatening habitat quality in its source populations. While delta smelt are probably not directly affected by *Microcystis* blooms, the source populations of its preferred prey may be threatened in the Delta. The proposed project will address how *Microcystis* affects the feeding ecology of and habitat quality of zooplankton, focusing on copepods, making it possible to predict impacts to *P. forbesi* and its source populations.

This research will benefit the first CALFED priority area: Trends and Patterns of Habitats, Populations and System Response to a Changing Environment, where the goal is to develop research that includes responses of primary production, habitat quality and connectivity, ecosystem function and ecosystem services. We propose to quantify mechanisms by which *Microcystis* blooms can change phytoplankton food and subsequent habitat quality, as well as the pelagic ecosystem function. In addition, results can be used to predict how *Microcystis* impacts spread within the SFE due to foodweb connectivity and leakage of effects. Specifically, we will help explain how *Microcystis* impacts in the freshwater Delta of the SFE can affect zooplankton abundances in the low salinity zone, which is the summer habitat for many fish species. In addition, the proposed project will benefit CALFED's second priority area of Aquatic Invasive Species, by predicting the foodweb response to *Microcystis*, one of the species of concern.

Once developed, the use of DNA based biomarkers to monitor in-situ zooplankton ingestion of *Microcystis* will provide a simple and highly effective indicator of the fate of this toxic cyanobacteria in the pelagic foodweb as well as provide an advanced method to monitor species specific exposure in the future. Benefits from the application of this method will extend beyond the SFE, as *Microcystis* blooms

are causing problems in many parts of California, including the Russian River and Klamath River reservoirs.

Effective management actions to improve pelagic ecosystem function require more detailed investigations into the causes and mechanisms of the declines (Sommer et al 2007). Overall, CALFED and especially the POD management team will benefit from the results and predictions of this project because it will clarify the trophic interactions and feeding ecology of highly significant zooplankton species as a function of *Microcystis* abundance and strain, explaining the potential variation in zooplankton due to *Microcystis*. Specific products will be available as follows.

Project Timeline

Year 1: January 2009 - January 2010

- Prepare laboratory supplies and start copepod and *Microcystis* cultures (January – March 09)
- Develop PCR detection of *Microcystis* in *P. forbesi*, calibrate with radiolabels, quantify ingestion rates (March 09 – July09)
- Determine in-situ ingestion in field and effects on community (July 09 – October 09)
- Develop PCR analysis of field ingestion (October 09 – January 10)

Year 2: January 2010 – January 2011

- Data analysis, report and manuscript preparation (January 10 – March 10)
- Determine ingestion under pre-bloom conditions (March 10 - June 10)
- PCR analysis to determine effects on pre-bloom community (June 10-August 10)
- Data analysis, report, and manuscript preparation (August 10 – January 11)

Potential peer-reviewed publications that will result from this project can include: 1) Development of qPCR method for in-situ *Microcystis* ingestion, 2) In-situ ingestion of *Microcystis* in field zooplankton using qPCR, 3) Role of *Microcystis* in the survival, ingestion, and zooplankton community shifts in the SFE.

Benefits to fellow: I am a graduate student at UC Davis, working on toxic and nutritional effects of *Microcystis* on copepods in the laboratory. Continuing to work on *Microcystis*-zooplankton interactions is a logical step, and extending research beyond the laboratory to the actual foodweb implications using novel methods is highly attractive way to get involved in developing my interests, knowledge base, and skills. I will gain valuable experience by designing and managing several experiments, working with and meeting new colleagues from various scientific backgrounds and agencies, and first-hand exposure to the management challenges facing one of the most heavily impacted estuaries in the world. This is a fascinating opportunity to learn new skills, be in a stimulating environment for research ideas, meet future collaborators, and to prepare for a career in coastal ecology and management. The proposed work will create at least three manuscripts to be published in peer-reviewed journals which will help build my career. Additionally, I will be receiving post doctoral training in laboratory management, teaching, writing, and interviewing skills from Dr. Kimmerer. Finally, this project will get me further involved with my interest to look at changes in coastal foodweb processes and ecosystem function due to human activity.

Benefits to research mentor: Dr.Wim Kimmerer has several ongoing projects dealing with food abundance for pelagic fish. Processes that affect zooplankton abundance and diversity directly relate to and enhance these projects. Understanding the effects of changes in growth rate and mortality processes is key to understanding changes in abundance. Although traditionally studies of these processes have

focused on food quantity and predation, there is growing interest in the effect of food quality and specifically biogenic toxins, which can influence zooplankton and fish through a variety of mechanisms.

Benefits to community mentor: Dr. Anke Mueller-Solger will be involved with the development and application of novel methods to quantify the fate and impact of *Microcystis* to the pelagic foodweb. As a senior environmental scientist at the Department of Water Resources, and the current chair of the POD Management Team, Dr. Mueller-Solger has extensive experience with trophic interactions and food limitation in the pelagic foodweb, a genuine interest in alternative trophic pathways at the base of the foodweb, and a desire to see new molecular methods such as DNA based biomarkers to quantify trophic interactions.

Benefits to CALFED: Improving water quality, ecosystem health and function, and reversing the decline in the pelagic foodweb of the SFE are central objectives of CALFED. The recent decline in pelagic fish and the listing of Delta smelt have put pressure to find causes of such trends, yet it has become clear that a more holistic understanding of the pelagic foodweb is necessary for reversing the decline in pelagic fish and their dominant food source. The increasingly frequent *Microcystis* blooms present a potential threat to CALFED's basic objectives of supporting water quality and ecosystem health. Please see above for the specific benefits to CALFED management objectives.

References cited

Anderson D. and Garrison D. 1997. Preface to the special issue for the Ecology and Oceanography of Harmful Algal Blooms. LIMNOLOGY AND OCEANOGRAPHY, 42(5) part 2.

Bay Delta Tributaries Project. Online Database available at http://bdat.ca.gov

Bouley, P. and W.J. Kimmerer. 2006. Ecology of a highly abundant, introduced cyclopoid copepod in a temperate estuary. MARINE ECOLOGY PROGRESS SERIES 324: 219-228.

Chorus I and Bartram J (Eds). 1999. Toxic Cyanobacteria in Water: A Guide to Their Public Health Consequences, Monitoring, and Management. SPON Press, on behalf of the World Health Organization.

Christoffersen K. 1996. Ecological implications of cyanobacterial toxins in aquatic food webs. PHYCOLOGIA, v. 35(supplement 6): 42-50.

DeMott WR, and Moxter F. 1991. Foraging on cyanobacteria by copepods: responses to chemical defenses and resource abundance? ECOLOGY, 75(5): 1820-1834

.

DeMott WR.1995. Food selection by calanoid copepods in response to between-lake variation in food abundance. FRESHWATER BIOLOGY, 33 (2), 171–180

DeMott WR and Tessier A. 2002. Stoichiometric constraints vs. algal defenses: testing mechanisms of zooplankton food limitation. ECOLOGY, 83(12):3426-3433.

Ghaouani A, Pinel-Alloul B, Prepas EE. 2003. Effects of experimantall induced cyanobacterial blooms on crustacean zooplankton communities. FRESHWATER BIOLOGY, 48:363-381.

Gasparani S and Castelt J. 1997. Autotrophic and heterotrophic nanoplankton in the diet of the estuarine copepods *Eurytemora affinis* and *Acartia bifilosa*. JOURNAL OF PLANKTON RESEARCH 19(7):877-890.

Gasparini S, Castel J, Irigonen X .1999 Impact of suspended particulate matter on egg production of the estuarine copepod, *Eurytemora affinis.* JOURNAL OF MARINE SYSTEMS, 22(2-3):195-205

Ger KA, Teh SJ, Goldman CR. 2007 – SUBMITTED. Acute and Chronic effects of dissolved MC-LR on survival and population growth of dominant calanoid copepods of the San Francisco Estuary

Graneli, E; Turner, JT (Eds). 2006. Ecology of Harmful Algae, Ecological studies 189. Springer ISSN 0070-8356

Hansson L-A, Gustaffson S, Rengefors K, Bomark L. 2007. Cyanobacterial chemical warfare affects zooplankton community composition. FRESHWATER BIOLOGY 52:1290-1301.

Hargis JR. 1977. Comparison of techniques for the measurement of zooplankton filtration rates. LIMNOLOGY AND OCEANOGRAPHY, 22(5):942-945.

Hoffmann GE and Gaines SD. 2008. New Tools to Meet New Challenges: Emerging Technologies for Managing Marine Ecosystems for Resilience. BIOSCIENCE 58(1):43-52.

Jassby, AD, Cloern JE, Cole BE. 2002. Annual primary production: patterns and mechanisms of change in a nutrient rich tidal ecosystem. LIMNOLOGY AND OCEANOGRAPHY, 47(3):698-712

Kimmerer, W. 2004. Open Water Processes of the San Francisco Estuary: From Physical Forcing to Biological Responses. San Francisco Estuary and Watershed Science. Vol. 2, Issue 1 (February), Article http://repositories.cdlib.org/jmie/sfews/vol2/iss1/art1

Kirk K, Gilbert J. 1992. Variation in herbivore responses to chemical defenses zooplankton foraging on toxic cyanobacteria. ECOLOGY, v. 73 (6): 2208-2217.

Koski M, Engstrom, J, Viitasalo, M. 1999. Reproduction and survival of the calanoid copepod *Eurytemora affinis* fed with toxic and non-toxic cyanobacteria. MARINE ECOLOGY-PROGRESS SERIES, v186: 187-197

Kumar R. 2003. Effect of different food types on developmental rates and demographic parameters of *Phyllodiaptomus blanci* (Copepoda:Calanoida). ARCHIVES FUR HYDROBIOLOGIE v. 157(3):351-377.

Lampert W. 1987. Laboratory studies on zooplankton-cyanobacteria interactions. NEW ZEALAND JOURNAL OF MARINE AND FRESHWATER RESEARCH, 21: 483-490.

Lehman PW, Boyer G, Hall C, Waller S, Gehrts K. 2005. Distribution and toxicity of a new colonial *Microcystis aeruginosa* in the San Francisco Bay Estuary, California. HYDROBIOLOGIA, 541:87-99.

Lehman PW, Boyer G, Satchwell M, Waller S. 2008, The influence of environmental conditions on the seasonal variation of Microcystis cell density and microcystins concentration in San Francisco Estuary. HYDROBIOLOGIA, 600:187-204

Muller-Solger, A, Jassby AD, Muller-Navarra D. 2002. Nutritional quality of food resources for zooplankton (*Daphnia*) in a tidal freshwater system (Sacramento-San Joaquin River Delta). LIMNOLOGY AND OCEANOGRAPHY, 47(5): 1468-1476.

Mueller-Solger AM, Hall CJ, Jassby AD, and Goldman CR. 2006. Food resources for zooplankton in the Sacramento-San Joaquin Delta. Final Report to the Calfed Ecosystem Restoration Program, May 2006.

Nadini S. 2003. Responses of rotifers and cladocerans to *Microcystis aeruginosa*: A demographic study. AQUATIC ECOLOGY 34:227-242.

Nejstgaard JC, Frischer ME, Simanelli P, Troedsson C, Brakel M, Adiyaman F, Sazhin AF, Artigas LF. 2008. Quantitative PCR to estimate copepod feeding. MARINE BIOLOGY, 153:565-577.

Ouellette JA and Wilhelm S. 2003. Toxic cyanobacteria: the evolving molecular toolbox. FRONTIERS IN ECOLOGY AND ENVIRONMENT, 1(7):359-366.

Oberholster PJ, Botha AM, Cloete TE. 2006. Use of molecular markers as indicators for winter zooplankton grazing on toxic benthic cyanobacteria in an urban Colarado Lake. HARMFUL ALGAE, 5:705-716.

Paerl HW. 1988. Nuicance phytoplankton blooms in coastal, estuarine, and inland waters. LIMNOLOGY AND OCEANOGRAPHY, 33(4,part2):823-847.

PanossoR, Carlsson P, Kozlowsky-Suzuki B, Azevedo SMFO, Graneli E.2003. Effect of grazing by a neotropical copepod Notodiaptomus, on a natural cyanobacterial assemblage of toxic and non-toxic cyanobacterial strains. JOURNAL OF PLANKTON RESEARCH, 25(9):1169-1175.

POD Management Team 2007. 2007. Pelagic Organism Decline Progress Report: Synthesis of Results. Baxter R, Rich Breuer R, Chotkowski M, Feyrer F, Gingras M, Herbold B,Mueller-Solger AM, Nobriga M, Sommer T, Souza K.

Reynolds, CS and Jaworski GHM. 1978. Enumeration of natural *Microcystis* Populations. BRITISH PHYCOLOGY JOURNAL, 13: 269-277.

Rohrlack T, Christoffersen K, Dittmass E, Nogueira I, Vasconcelos V, Borner, T. 2005. Ingestion of microcystins by Daphnia: Intestinal uptake and toxic effects. LIMNOLOGY AND OCEANOGRAPHY, 50(2):440-448.

Smith AD, Gilbert LG. 1995. Relative susceptibilities of rotifers and cladocerans to *Microcystis aeruginosa*. ARCHIV FUR HYDROBIOLOGIE, 132(3):309-336.

Stahl-Delbanco A. Hansson L, and Gyllstrom. 2003. Recruitment of resting stages may induce blooms of Microcystis at low N:P ratios. JOURNAL OF PLANKTON RESEARCH, 25(9):1099-1106.

Stibor H, Vadstein O, Diehl S, Hansen T, Hantzche F, Katechakis A, Lippert B, Loseth K, Peters C, Roederer W, Sandow M, Sundt-Hansen L, Olsen Y. 2004. Copepods act as a switch between alternative trophic cascades in marine pelagic foodwebs. ECOLOGY LETTERS, 7:321-328.

Sommer T, Armor C, Baxter R, Breuer R, Brown L, Chotkowski M, Culberson S, Feyrer F, Gingras M, Herbold B, Kimmerer W, Mueller-Solger A, Nobriga M, Souza K. 2007. The collapse of pelagic fishes in the upper San Franciso Estuary. FISHERIES,32(6): 270-277.

Wilson, AE; Sarnelle, O; Tillmanns, AR. 2006. Effects of cyanobacterial toxicity and morphology on the population growth of freshwater zooplankton: Meta-analyses of laboratory experiments. LIMNOLOGY AND OCEANOGRAPHY, 51(4): 1915-1924.

Zurawell RW, Chen H, Burke JM, Prepas EE. 2005. Hepatotoxic cyanobacteria: A review of the biological importance of microcystins in freshwater environments. JOURNAL OF TOXICOLOGY AND ENVIRONMENTAL HEALTH, Part B, 8:1-37.

FISCAL YEAR Start Date: 15/01/09 (mm/dd/yy) End Date: 14/01/10

PROJECT NUMBER	Dr. Wim Kimmerer NAME OF MENTOR
INSTITUTION Romberg Tiburon Center, San Francisco State University	K. Ali Ger NAME OF FELLOW

		CALFED FUNDS
A. EXPENDABLE SUPPLIES AND EQUIPMENT		
1. PCR Kits, TaqMan universal PCR master mix (200rxn)		2,500
2. DNA probe QIAamp DNA Mini kit (250 preps)		1,000
3. DNA sequencing		500
4. PCR primers		500
5. Technician time		700
6. Algal and zooplankton culture supplies		800
7. Computer supplies		500
8. Trips to UCD from RTC, SFSU	$0.48 per mile	480
	TOTAL SUPPLIES	6,980
B. PERMANENT EQUIPMENT		
1.		
2.		
3.		
4.		
5.		
	TOTAL EQUIPMENT	
C. TRAVEL		
1. DOMESTIC-U.S. AND ITS POSSESSIONS		500
2. INTERNATIONAL (INCLUDING CANADA AND MEXICO)		
	TOTAL TRAVEL	500
D. PUBLICATION AND DOCUMENTATION COSTS	TAL PUB COSTS	
E. OTHER COSTS		
1. Fellowship Stipend (review call for proposals)		45,000
2.		22,500
3.		
4.		
5.		
6.		
	TOTAL OTHER COSTS	67,500
F. TOTAL DIRECT COSTS *(A THROUGH E)*	TOTAL DIRECT COSTS	74,980
G. INDIRECT COSTS		
ON CAMPUS 25.0% OF 25,800		7,495
OFF CAMPUS 25.0% OF		
	TOTAL INDIRECT COSTS	7,495
H. TOTAL COSTS	TOTAL COSTS	82,475

Prepared by: _____ Admin Contact: _____

Phone: _____ Phone: _____

Fax: _____ Fax: _____

E-mail: _____ E-mail: _____

DATE: _____

YEAR 2 Start Date: (01/15/10) **End Date: 1/14/2011**

ANNUAL BUDGET — Dr. Wim Kimmerer

PROJECT NUMBER — **NAME OF MENTOR**

K. Ali Ger

INSTITUTION Romberg Tiburon Center, San Francisco State University — **NAME OF FELLOW**

		CALFED FUNDS
A. EXPENDABLE SUPPLIES AND EQUIPMENT		
1. PCR Kits, TaqMan universal PCR master mix (200rxn)		2,000
2. DNA probe QIAamp DNA Mini kit (250 preps)		1,000
3. DNA sequencing		500
4. PCR primers		300
5. Technician time		500
6. Carboys, beakers, flasks, air tubes		300
6. Boat use		525
7. Sampling Trips To Delta $0.48 per mile		240
	TOTAL SUPPLIES	5,365
B. PERMANENT EQUIPMENT		
1.		
2.		
3.		
4.		
5.		
	TOTAL EQUIPMENT	
C. TRAVEL		
1. DOMESTIC Conference -U.S. AND ITS POSSESSIONS		200
2. INTERNATIONAL Conference (INCLUDING CANADA AND MEXICO)		1,750
	TOTAL TRAVEL	1,950
D. PUBLICATION AND DOCUMENTATION COSTS	TAL PUB COSTS	150
E. OTHER COSTS		
1. Fellowship Stipend (review call for proposals)		45,000
2. Benefits at 48% of stipend		22,500
3.		
4.		
5.		
6.		
	TOTAL OTHER COSTS	67,500
F. TOTAL DIRECT COSTS *(A THROUGH E)*	TOTAL DIRECT COSTS	74,965
G. INDIRECT COSTS		
ON CAMPUS 25.0% OF 25,800		7,491
OFF CAMPUS 25.0% OF		
	TOTAL INDIRECT COSTS	7,491
H. TOTAL COSTS	TOTAL COSTS	82,456

DATE:

Prepared by: Administrative Contact:

Phone: Phone:

Fax: Fax:

E-mail: E-mail:

CUMULATIVE BUDGET

PROJECT NUMBER	NAME OF MENTOR
INSTITUTION	**NAME OF FELLOW**

	CALFED FUNDS
A. EXPENDABLE SUPPLIES AND EQUIPMENT	12,345
B. PERMANENT EQUIPMENT	
C. TRAVEL	
1. DOMESTIC-U.S. AND ITS POSSESSIONS	700
2. INTERNATIONAL (INCLUDING CANADA AND MEXICO)	1,750
D. PUBLICATION AND DOCUMENTATION COSTS	150
E. OTHER COSTS	135,000
F. TOTAL DIRECT COSTS *(A THROUGH E)*	149,945
G. INDIRECT COSTS	14,986
H. TOTAL COSTS	164,931

Budget Justification

Stipend
Postdoctoral Science Fellow, two years stipend at $45,000 per year

Benefits
The benefit rate of San Francisco State University is $25,800 annually

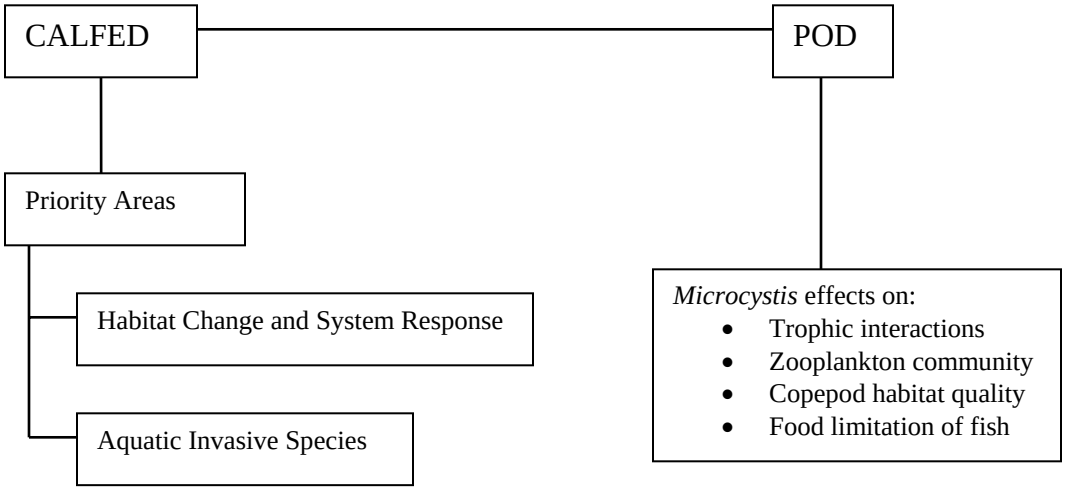
Travel
Funds are set aside for travel between UC Davis and RTC, during the development of the qPCR method, in collaboration with Dr. Swee Teh and Dr. Dolores Baxa. Further trips to sample from the SFE will be necessary and included in the budget as well. Travel to conferences are also included.

Expendable supplies and equipment
The main expense with equipment will go towards PCR supplies, primers, pipette tips, several reagents and buffers to run assays, and kits manufactured by Applied BioSciences.

Links to the CALFED program

Our proposal directly addresses two different CALFED priority areas: 1) Trends and Patterns of Habitats, Populations and System Response to a Changing Environment; and 2) Aquatic Invasive Species. In addition, the proposed work investigates several key questions under the POD program, which is a CALFED implementing agency. Specifically, we will collect information on the quantitative relationship between *Microcystis* blooms (a species of concern under CALFED's priority areas), and the response of zooplankton community dynamics, which is a critical food source to pelagic fish species including Delta smelt. Thus, we will develop research that includes responses of primary production, habitat quality and connectivity, as well as foodweb and ecosystem function. Does *Microcystis* reduce the habitat quality of preferred fish prey such as *P. forbesi*? What zooplankton species benefit and suffer from increased *Microcystis*? Are there predictable changes in estuarine foodwebs due to *Microcystis* blooms? The answer to these and other questions directly pertain to CALFED's priority areas for this fellowship as well the its long-term goal to improve water quality, ecosystem health and function, and reversing the decline in the pelagic foodweb.

See the conceptual diagram below to visualize the links between proposed work and the CALFED program.



Statement of Purpose – Kemal Ali Ger

From Turkey, I decided to come to the US during my sophomore year in college, to get a better education in coastal ecology and environmental science in general. Currently I am in the final year of my doctoral work and am ready to graduate into a postdoctoral position to get further experience, perspective, and expertise in the progressive developments in ecology and its applications to management issues.

During parts of my undergraduate work at the Ecology, Evolution, and Marine Biology Department of UC Santa Barbara, what seemed as esoteric academic research disappointed me. Though not entirely knowing what it meant at the time, to evade what I saw as academic rhetoric, a more interdisciplinary program for my master's seemed as a better route. After attending Duke University's School of the Environment for a year, I continued my masters at UC Santa Barbara, where I graduated June 2002 with a degree from the Environmental Science and Management Program, concentrating in coastal management. A great deal about the actual manifestation of interdisciplinary research and its potential pitfalls became clear. Simultaneously, I enjoyed learning about how different environmental sciences are inherently linked conceptually, yet separated politically. It was an environment where the student is responsible for making the most of what is offered. I made the most of it by taking courses and research opportunities that familiarized me with processes that interest me: identifying links between human activity and ecosystem processes.

My interests and experience focus around the relationships between watersheds and coastal ecosystems, nutrient/runoff impacts on food web dynamics and species composition, whether ecological degradation makes systems more susceptible to invading exotics, bridging the gap between 'local' knowledge and scientific knowledge, as well as science and policy. Although my interests are DEEPLY rooted in science, I am still interested in the social implication of the science and its findings. I want to improve my skills in quantitative analysis of environmental problems associated with my interests, so it is easier to provide accurate and useful information for effective decisions.

Because coastal environments exist at the land-sea-air interface, affected by changes in any or all of these components, I would like to be part of a larger research agenda which assumes that coastal systems are now changing in response to the combined effects of natural and anthropogenic processes, that these changes will likely accelerate in the coming decades, and that the ecology of these systems is likely to be different within the working lives of younger students such as myself. I am interested in research where the focus is broad with respect to the interactions between the different ecosystem processes (like primary production, food web dynamics, pollution, runoff, sedimentation, land use, invading exotics, fisheries, climate, etc), and narrow in regard to the subject context (organism responses), which all the processes act on. There is little doubt of the linkage between different ecological processes. The question is how to link and study the different interacting mechanisms so they make sense. The challenge of how to link different components to make sense out of human impacts on ecosystem processes thrills me.

In the past, I had experience with asking questions that helped uncover such links between ecosystem processes and human activity. For example, the effect of runoff and coastal eutrophication on the marine food web; the effect of how degraded an ecosystem is on the potential destructiveness of invading exotics; modeling impacts of exotics in the Black Sea; identifying/modeling the combined effects of fishing and coastal development on the coastal food web; the difference between no-take reserves and a management scheme that is more inclusive of fishers (reuniting use with conservation). Continuing to work on similar research with a similar approach is essential for me.

In Turkey, I was part of a large-scale population monitoring experiment for Loggerhead sea turtles on the south coast of Turkey. Living on the beach for a couple of months was not only fun, but it taught the importance of getting along with locals: without their understanding of the turtles condition, our research

would have much less relevance. At UCSB, I worked at the soil ecology lab. Though not my most passionate interest, I learned more about experimental design and statistical analysis of the results. Internships provided me with a variety of professional experience and an active role to reduce the lack of communication between science and policy. Working at the Channel Islands National Marine Sanctuary, and Audubon's San Francisco Bay Restoration Program, I gained valuable experience about the types of information demanded and used by the regulatory framework. Observing hopeless animosity between scientists and fishers, and other stakeholders, convinced me even more to do a PhD intending to reduce the malfunctions of the current regulatory framework by exposing underlying ecosystem processes so that prevention of ecological damage is a possibility.

My masters thesis was a group collaboration modeling the feasibility of adding seep tents to obtain methane and improve air quality by using an integrative model that linked the seep flux to air quality and economic analysis (we found it was not that feasible for any aspects we looked at: environmental benefits too low, politically unattractive, financially too expensive). Working on several issues, I focused on the benthic seep ecology, and the seeps effect on local water quality. That research has extended to my previous job, where I managed research for identifying and analyzing risks associated with the expansion of a local oil platform (Holly) for the Environmental Defense Center in Santa Barbara.

During my PhD years in Davis, I had the opportunity to work in several aquatic research projects, mostly in applied ecology. I spent three summers at the UC Davis Catle Lake Limnology Laboratory, a field station in the Shasta-Trinity forest, conducting standard limnological sampling and analysis for a lake that has one of the longest continuous datasets in the world. My final year there, I was the manager of all station operations, which gave me valuable experience in terms of project design, management, logistics, and finding practical solutions in a field setting where resources are limited.

Once I became involved with the emerging *Microcystis* blooms of the Delta, I chose this as a research theme for my thesis, and have been working on its toxic and nutritional impacts to the San Francisco Estuaries critical zooplankton species. It has always been my goal to increase my involvement with ecosystem management, and ecological research applied to provide accurate diagnosis of management complexities in coastal and aquatic systems. The decline of pelagic species in the San Francisco Estuary, one of the most impacted estuaries globally, is a great place to begin a career in applied coastal ecology. Given my background and experience in foodweb dynamics, I am looking forward to apply my skills to face the complexities of the pelagic organism decline.

KEMAL ALI GER

1403 Oak Avenue
Davis, CA 95616
(530) 757-7735 kager@ucdavis.edu

EDUCATION

PHD Graduate Student
Graduate Group in Geography, UC Davis.
Concentration: Coastal systems ecology and management, harmful algal blooms.
GPA 3.88

MASTER OF ENVIRONMENTAL SCIENCE AND MANAGEMENT
Donald Bren School of Environmental Science & Management
University of California, Santa Barbara. June 2002, GPA 3.81
Concentration: Marine Resource Management

BACHELOR OF SCIENCE, ECOLOGY AND EVOLUTION
University of California, Santa Barbara. June 1999
Honors: Graduated high honors, GPA: 3.75 out of 4.0, Dean's list 6 quarters

Additional Education:

Duke University, Nicholas School of the Environment (1999-2000)
Courses include: GIS, Biodiversity Policy, Wetlands Ecology, Coastal Zone Management
Hacettepe University, Ankara, Turkey (1995-1996)
Courses include: General Biology

EXPERIENCE

Graduate Student Researcher (09/04-current)
Aquatic Toxicology, UC Davis, CA.
Assessment of interactions between the toxic alga *Microcystis* and zooplankton, with implications for impacts on greater aquatic ecosystem in the upper San Francisco Estuary. Focus on identification of mechanisms (direct toxicity, food quality, bioaccumulation, and inhibitory effects). Tasks consist of project and experimental design, methods development (culturing of algae, zooplankton, fish), field sampling, data analysis, and literature review.

Manager/Post Graduate Researcher (6/05-9/05, 6/04-9/04, and 6/03-9/03)
UC Davis Castle Lake Limnological Laboratory, CA.
Member of the summer fieldwork crew, collected standard limnological samples and analysis, including water chemistry, chlorophyll, zooplankton, and primary production. Design experimental sampling for new projects such as bacterial ecology and human impacts. Manager of laboratory operations during summer 2005.

Graduate Research Assistant (01/04-06/04)
John Muir Institute for the Environment, UC Davis, CA.
Looking at water chemistry (DOC, DIC) and bacterial biomass as a parameter to estimate fish diversity in restored wetlands and floodplain of the Cosumnes River. Fieldwork includes several sampling points, experimental design. Duties also include analysis of samples.

Fellow/Consultant (8/02-6/03)
Environmental Defense Center, Santa Barbara, CA.
Managing the research for identifying the likely risks associated with Venoco's offshore oil and gas expansion plans. Additionally analyzing some of the selected risks, identifying experts for possible collaboration and research, and formulating research questions for further analysis. Selected to position through a fellowship grant.

EXPERIENCE (CONTINUED)

Research Assistant (9/01-6/02)
Coastal Ocean Policy Center, U.C. Santa Barbara
Researched several issues in-depth for different white papers about the threats and health of southern California marine ecosystems and the connections between the Gaviota watersheds and marine ecosystem integrity. Focused on the likely terrestrial and marine impacts of proposed development of these watersheds.

Environmental Careers Organization, Summer Fellow (6/01-9/01)
Audubon San Francisco Bay Restoration Program, San Francisco, CA
Researched several key case studies of recent and proposed wetland mitigation projects though interviews, permits, and environmental documentation. Developed a format to apply these studies as specific examples to be used in the Program's Mitigation Report, which is a detailed analysis and recommendation for future mitigation in the Bay.

Marine Reserve Intern (1/01-6/01)
Channel Islands National Marine Sanctuary, NOAA, Santa Barbara, CA
Prepared consistency reviews of different agencies and statutes goals and objectives to identify the common goals and contrast the conflicting goals to better the interagency cooperation. Evaluated scientific papers and conducted policy and media research. Observed conflict resolution meetings.

Research Assistant (10/98-6/99)
Ecology, Evolution, and Marine Biology Department, U.C. Santa Barbara.
Investigated how soil function changes with different disturbance levels. Focused on soil ecology as a function of microbe varieties. Helped design experiments and field research.

Research Assistant (Summer 1996)
Biology Department, Hacettepe University, Turkey
Researched the population dynamics of the Loggerhead sea turtle's (*Caretta caretta*) population in the southeastern Mediterranean coast of Turkey. Participated in fieldwork and collection and analysis of data. Lived on the beach where research took place, responsible for communication with the locals about significance of research.

ADDITIONAL INFORMATION

Certified PADI Advanced open water diver.
Proficient in Excel, Arc/Info, Word, S-Plus.
Bilingual in Turkish and English.

Plan for collaborating with community mentor

I look forward to working closely and regular communication with Dr. Mueller Solger during every part of the proposed project. Her vast knowledge about the pelagic foodweb, ecology of invasions, nutrient dynamics, and experience in designing and overseeing experiments and monitoring programs will be a great resource for me. I plan on setting up meetings, and more frequently, telephone and email communication during my project. She will provide me with insights, suggestions for other people to contact, scientific and practical advice when developing the project.

She is the current chair of the POD management group and is familiar with the demands of managing a highly impacted estuary such as the SFE. As such, she will be helpful in directing the results and information this project generates. Specifically, she can help me put the results in a context that is more useful for management implications, as well as suggest ways to improve potential problems that may arise during the project due to unforeseen events. In short, her experience in management and practical solutions will help me adapt the project when necessary. Overall, it will be great to benefit from her advice through continuous communication about the progress of this project.

CALFED Project Summary Form - California Sea Grant

Title: Trophic Impacts of Microcystis on the crustacean zooplankton community of the Delta

Type of Fellowship: Postdoctoral

Initiation Date: 01/15/2009

Completion Date: 01/14/2011

	Last	First	Initial		
CALFED Fellow:	Ger	K. Ali		**Effort:**	
Affiliation:	University of California, Davis			**Affil. Code:**	0609
Research Mentor 1:	Kimmerer	Wim		**Effort:**	
Affiliation:	Romberg Tiburon Center, San Francisco State			**Affil. Code:**	
Research Mentor 2:				**Effort:**	
Affiliation:				**Affil. Code:**	
Community Mentor 1:				**Effort:**	
Affiliation:				**Affil. Code:**	
Community Mentor 2:				**Effort:**	
Affiliation:				**Affil. Code:**	

Total CALFED Funds: 164,931

Related Projects:

Parent Projects:

Key Words:

Objectives:

We will test the hypothesis that Microcystis abundance causes predictable shifts in the SFE's zooplankton community with a series of laboratory experiments and field measurement of in-situ ingestion rates. The objective of the proposed project is to 1) develop a calibrated qPCR based method to quantify in-situ Microcystis ingestion using target zooplankton species, 2) apply this method in field mesocosm and laboratory feeding experiments to quantify in-situ ingestion of Microcystis and subsequent changes in zooplankton survival and community composition, and 3) compile results to determine impacts to zooplankton community composition. This will help to identify management alternatives specific to the Delta through a comparison to other affected estuaries around the world. The objectives will answer the following questions:

- How useful is qPCR as a monitoring tool for Microcystis ingestion?
- What are the trophic dynamics by which Microcystis changes the zooplankton community composition?
- Does Microcystis reduce the habitat quality of preferred fish prey such as P. forbesi?
- What zooplankton species benefit and suffer from increased Microcystis?

Methodology:

A combination of techniques will be used to quantify in-situ ingestion rates of zooplankton in the field and in laboratory under controlled conditions. Our aim is to determine a potential relationship between Microcystis abundance and the change in zooplankton species composition based on species-specific ingestion and survival rates. Results can be used to model the zooplankton community response (survival, species composition) to various scenarios of Microcystis abundance (biomass, toxicity, duration) to understand the role that Microcystis plays in food limitation of pelagic fish in the SFE.

A large quantity of P. forbesi will be used in the experiments. Small (4L beakers) batch cultures as well as a large mass culture (50 – 100 L) will be maintained to ensure enough test organisms. Microcystis cultures will be maintained in a separate room under light- and temperature-controlled conditions.

Various strains of Microcystis will be obtained from the University of Texas Culture Collection (UTEX), including strains that do not produce microcystin (MC) toxins (UTEX 2386), which will be used as an additional control for Microcystis MC content during the ingestion study.
Copepods will be fed Microcystis and collected for qPCR analysis as described below. A factorial design of three diet concentrations for at least two different (MC+ and MC-) strains of Microcystyis (25%, 50% and 100% Microcystis diet by carbon, bringing the total food to 500 µgC.L-1.day-1 using Instant Algae). In a separate section of the laboratory authorized for the use of radioactive substances, radiolabeled 14C Microcystis will be fed to copepods as an independent measure of ingestion. Rinsed copepods will be filtered or collected in scintillation vials (in groups of 20-30/replicate) and stored for analysis by liquid scintillation (Hargis 1977, Rohrlack 1999).
Both zooplankton and Microcystis will be collected from the same site using surface tows, with measures taken to minimize the release of toxins from damaged Microcystis to zooplankton during the tow. Microcystis is generally patchy in its distribution, forming aggregated scums due to wind and wave action. We will take advantage of this patchy distribution and collect zooplankton where Microcystis is minimal, and within the same general site, and collect Microcystis where it is most dense. Zooplankton in carboys will be brought to RTC within two hours of each collection and separated into species, rinsed with filtered surface water from the same site and immediately frozen in liquid nitrogen to prevent the loss of gut contents. Specific zooplankton included in analysis will be P. forbesi, E. affinis, A. sinensis, L. tetraspina, as well as other copepods and cladocera if time permits. Using the carboys from above, we will evaluate the impact of Microcystis abundance on in-situ grazing rates, survival, and change in species composition (abundance of species x/total species abundance) of zooplankton. To do this, we will set up 20 L mesocosms in a light and temperature controlled chamber, and vary initial Microcystis biomass. There will be three treatments (low, ambient, and high Microcystis), and two replicates.
We will use commercially available primers for use in a rapid and specific PCR test to detect the presence of cyanobacteria, Microcystis (MC+ and MC- strains), and toxic Microcystis (MC+ only) based on the toxin genes microcystin peptide synthetase B (mcyB) and microcystin polyketide synthase D (mcyD). Probes will be designed following the specifications of Applied BioSciences (Foster City, CA), and probe specificity will be tested on various Microcystis strains before the probes are used for field samples.

Rationale:

The recent decline in the pelagic foodweb of the upper San Francisco Estuary (SFE) has caused widespread concern in management agencies and the public. Abundances of several pelagic fish species have declined to historically low levels, and the apparent slide to extinction of the Delta smelt, along with the consideration of longfin smelt for listing, raise serious worries that the entire pelagic ecosystem may be affected. This broad decline across the foodweb has led to new ecological studies on multiple stressors and the consideration of several synergistic processes such as hydrographic changes, water quality, species introductions, food limitation, habitat quality and connectivity, and fisheries ecology. An ambitious multiagency research group has been studying the potential causes of the decline. Microcystis blooms have been a regular feature of the Delta for almost a decade, yet there is virtually no information on their impacts on the pelagic foodweb.
Seasonal blooms of the toxic colonial cyanobacteria Microcystis aeruginosa may have played a role in the decline in pelagic fish through changes in water quality and trophic interactions (POD Management Team 2007). High abundances of consumption-resistant algae such as Microcystis may impact the foodweb in three ways, 1) Reduce the quality of total phytoplankton biomass; 2) increase foodchain length by shifting zooplankton grazing to microbial sources, reducing overall zooplankton productivity; 3) change the zooplankton community composition by favoring smaller, non-herbivorous copepods such as cyclopoids, rotifers, and protozoans. A large body of research indicates that trophic impacts due to interference with grazing by herbivorous zooplankton can be substantial. Thus, there is good reason to believe that Microcystis blooms in the upper SFE could reduces phytoplankton food quality and thereby habitat quality for preferred pelagic fish prey such as Pseudidiaptomus forbesi.
Copepods dominate metazoan/mesozooplankton in the Delta and are the main food source for small pelagic fish. Calanoid copepods that can consume phytoplankton (E. affinis and P. forbesi) form shorter and more productive food chains that fuel the pelagic ecosystem. A decline in such copepods may signal alternative trophic pathways, in part due to Microcystis blooms, shifting the zooplankton towards non-herbivorous species, with likely consequences for food limitation of pelagic fish.

The trophic response of the pelagic foodweb to increased cyanobacterial primary production is governed by the identity of zooplankton and their feeding ecology. It is necessary to quantify in-situ grazing rates and feeding ecology of zooplankton to understand the dynamics of Microcystis impacts to the foodweb. Recent improvements in molecular methods such as quantitative PCR provide rapid and sensitive diagnosis for the identification of copepod diets based on prey DNA sequences, including Microcystis. The proposed project will apply this emerging method to track the species specific feeding ecology and response of the SFE's zooplankton community to Microcystis.

Anticipated accomplishments:

I have worked extensively with both copepods and algae, have experience measuring ingestion rates using radiotracers, designing, managing, and operating experimental systems in a laboratory setting, and maintaining continuous cultures. I also have several years of experience with various standard aquatic field sampling methods and analysis of physical, chemical, and biological parameters, both in the Delta and elsewhere (Cosumnes floodplain, Castle Lake, CA). I had the opportunity of closely observing and sampling Microcystis blooms since 2005, thanks to collaboration with Dr. Peggy Lehman, DWR. I have sampled and cultured zooplankton and Microcystis from the Delta in association with my current doctoral work. My current doctoral work investigates the acute and chronic toxicity, as well as the dietary effects of Microcystis in a mixed diet on the copepods P. forbesi and E. affinis under controlled laboratory conditions. I have one manuscript submitted on the acute and chronic toxicity of microcystin to copepods, and another in preparation about the selective feeding of copepods on Microcystis in their diet. The third manuscript will be submitted before this project begins. Quantifying the role Microcystis blooms play on the pelagic organism decline is a good match for my interests and experience.

Romberg Tiburon Center
For Environmental Studies

San Francisco State University

3152 Paradise Drive Tiburon, CA 94920
Tel (415) 338-3515 • Fax (415) 435-2100

June 6, 2008

CALFED Science Fellowship Program
California Sea Grant

Re: Application of Kemal Ger

I am writing to affirm my support for the application of Kemal Ali Ger for a CALFED Fellowship, and to commit to be his academic advisor should her application be successful. His proposed project, "Trophic Impacts of *Microcystis* on the crustacean zooplankton community of the Delta," addresses an issue that may be fundamental to understanding the recent Pelagic Organism Decline, and to future efforts at management and restoration.

The Pelagic Organism Decline refers to a decline in abundance of several fish species of the upper estuary, as well as some zooplankton species on which these fish feed. Several ongoing research efforts are aimed at answering some of the key questions about how the pelagic foodweb works. I am involved in several such projects with current funding from IEP and CALFED. Several colleagues at RTC, USGS, and elsewhere, and I are trying to determine the principal sources of organic carbon to the estuarine foodweb, how the carbon gets there, and how it makes its way to higher trophic levels, principally delta smelt. This project focuses on the foodweb but so far has not addressed the potential impact of either toxic effects of *Microcystis* or reduction in feeding rate due to blooms, both of which I now believe are potentially very important in the Delta. For example, in mid-summer of 2006 there was a die-back of copepods that we could not explain, except that it coincided with the spread of *Microcystis* into the low-salinity zone of the estuary.

Ali's Ph.D. dissertation research has consisted of laboratory studies of the effect of *Microcystis* on zooplankton. He has formed an informal alliance with my laboratory, exchanging information on culturing techniques, providing backup cultures of copepods, and generally providing intellectual support. Thus we have been working with him on an informal basis, and I am impressed with his energy and commitment to this topic.

There are three reasons why Ali would be a good choice for this fellowship. First, this is a topic of utmost importance and urgency: managers really need to know if toxic algae are disrupting the foodweb. Second, shifting the focus from the lab to the field would be a natural extension of Ali's dissertation research. Third, with his experience working with *Microcystis* and copepods and, this summer, developing qPCR techniques discussed in the proposal, Ali is well situated to begin the first careful examination of the effects of *Microcystis* on zooplankton in the estuary.

I would be happy to have Ali Ger in my laboratory to work on this project, and will provide him the necessary resources should he be successful.

Sincerely,

Wim Kimmerer, PhD
Research Professor
kimmerer@sfsu.edu

WIM J. KIMMERER, PH.D

Telephone:	(W)	(415) 338-3515
	(H)	(510) 848-7388
FAX:		(415) 435-7120
Email:		kimmerer@sfsu.edu
Web:		http://online.sfsu.edu/~kimmerer/

Current Position

Research Professor, Romberg Tiburon Center for Environmental Studies, San Francisco State University.

Education

University of Hawaii, Ph.D. 1980, Biological Oceanography
U.S. Navy Nuclear Power School, 1968.
Purdue University, B.S. 1967, Chemistry

Research and Professional Experience

1994-present	Senior Research Scientist & Research Professor, Romberg Tiburon Center
1986-1995	Senior Scientist, BioSystems Analysis Inc.
1982-1985	Research Fellow, University of Melbourne (Australia), Zoology Dept.
1980-1982	Research Associate/Assistant Director, Hawaii Institute of Marine Biology
1976-1980	Research Assistant, University of Hawaii
1973-1980	Graduate student, University of Hawaii
1972-1973	Flight instructor
1967-1972	U.S. Navy submarine force, final rank Lieutenant

Research Interests

The ecology of estuaries and coastal waters, with emphasis on the San Francisco Estuary. Influence of physical environment including freshwater flow, tidal currents, and turbulence on behavior, movement, and population dynamics of plankton and fish. Predatory control of species composition and abundance of plankton populations. Modeling of ecosystems, populations, and material cycling. Modeling and analyzing salmon populations in California's Central Valley. Human impacts on aquatic ecosystems and the interaction of science and management.

Other Professional Activities

- Member, Strategic Planning Core Team, CALFED Bay-Delta Program, 1998-99
- Co-Chair, Science Board, CALFED Bay-Delta Ecosystem Restoration Program, 2000-2005
- Co-founder and Past President, California Estuarine Research Society, the newest affiliate society of the Estuarine Research Federation.
- Chair, Estuarine Ecology Team, Interagency Ecological Program for the San Francisco Estuary.
- Advisor to the CALFED Lead Scientist

- Advisory committee, Georgia Coastal Estuaries LTER Program, J.T. Hollibaugh, PI.
- Invited participant in workshops at the University of Rhode Island (effects of freshwater flow on estuaries), Louisiana Universities Marine Consortium (coastal restoration), and the University of British Columbia (science needs for coastal management).
- Associate Editor, San Francisco Estuary and Watershed Science.
- Reviewer for professional journals including Limnology and Oceanography, Marine Biology, Marine Ecology Progress Series, Estuaries and Coasts, Estuarine, Coastal, and Shelf Science, ICES Journal of Marine Science, Hydrobiologia, Environmental Biology of Fishes.
- Reviewer of grant proposals for the National Science Foundation, EPA, and Seagrant offices.
- Steering committee, Bay-Delta Modeling Forum, 1995-2001
- Co-convenor, CALFED Ecosystem Restoration Program workshop on adaptive management, 2002
- Co-convenor, CALFED workshops on salmonids and delta smelt, 2001 and 2003, and Environmental Water Account review, 2006.
- Co-convenor, CALFED workshop on hatchery impacts on Battle Creek, California, 2003.
- Member, Steering Committe, Delta Risk Management Strategy (Department of Water Resources).

Recent and Current Students

Keun-Hyung Choi (research associate), Diego Holmgren, Karen Edwards, Lindsay Sullivan (post-docs); Heather Peterson, Lenny Grimaldo, Jena Bills, Paola Bouley, John Durand, Renny Talianchich, Allegra Briggs, Alison Gould, Laurie Kara, Valiere Greene (all Masters' students).

Selected Publications

Kimmerer, W.J., and A.D. McKinnon. 1987. Growth, mortality, and secondary production of the copepod *Acartia tranteri* in Westernport Bay, Australia. Limnol. Oceanogr. 32:14-28.

Kimmerer, W.J. and A.D. McKinnon. 1989. Zooplankton in a marine bay. III. Evidence for influence of vertebrate predation on distributions of two common copepods. Mar. Ecol. Progr. Ser. 53:21-35.

Kimmerer, W.J. and A.D. McKinnon. 1990. High mortality in a copepod population caused by a parasitic dinoflagellate. Mar. Biol. 107:449-452.

Kimmerer, W.J. 1991. Predatory influences on copepod distributions in coastal waters. Pp. 161-174 in S.I. Uye, S. Nishida, and J.-S. Ho, eds., Proceedings of the Fourth International Conference on Copepoda. Bull. Plankton Soc. Japan, Spec. Vol., Hiroshima

Kimmerer, W.J., S.V. Smith, and J.T. Hollibaugh. 1993. A simple heuristic model of nutrient cycling in an estuary. Estuarine, Coastal and Shelf Science 37:145-149

Kimmerer, W.J., E. Gartside, and J.J. Orsi. 1994. Predation by an introduced clam as the probable cause of substantial declines in zooplankton in San Francisco Bay. Marine Ecology-Progress Series 113:81-93.

Peterson, W.T. and W.J. Kimmerer. 1994. Processes controlling recruitment of the marine calanoid copepod *Temora longicornis* in Long Island Sound: Egg production, egg mortality, and cohort survival rates. Limnol. Oceanograph. 39:1594-1605.

Kimmerer, W.J. and J.R. Schubel. 1994. Managing freshwater flows into San Francisco Bay using a salinity standard: results of a workshop. Pp. 411-416 In K.R. Dyer and R.J. Orth (eds.), Changes in fluxes in estuaries. Olsen and Olsen, Fredensborg, Denmark.

Jassby, A.D., W. J. Kimmerer, S.G. Monismith, C. Armor, J.E. Cloern, T.M. Powell, J.R. Schubel, and T.J. Vendlinski. 1995. Isohaline position as a habitat indicator for estuarine populations. Ecological Applications 5:272-289

Kimmerer, W.J. and J.J. Orsi. 1996. Causes of long-term declines in zooplankton in the San Francisco Bay estuary since 1987. pp. 403-424 in San Francisco Bay: The Ecosystem. J.T. Hollibaugh (ed.). American Association for the Advancement of Science, San Francisco.

Kimmerer, W.J., W.A. Bennett, and J.R. Burau. 1998. Tidally-oriented vertical migration and position maintenance of zooplankton in a temperate estuary. Limnol. Oceanogr. 43: 1697-1709.

Kimmerer, W.J., J.H. Cowan Jr., L.W. Miller, and K.A. Rose. 2000. Analysis of an estuarine striped bass population: Influence of density-dependent mortality between metamorphosis and recruitment. Can. J. Fish. Aquat. Sci. 57: 478-486.

Kimmerer, W. 2000. Sacramento River Chinook Salmon Individual-based Model. Conceptual Model and Functional Relationships. Report to the US Fish and Wildlife Service, Sacramento CA.

Sommer, T, B. Harrell, M. Nobriga, R. Brown, P. Moyle, W. Kimmerer, and L. Schemel. 2001. California's Yolo Bypass: Evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture. Fisheries 26:6-16

Kimmerer, W.J., J.H. Cowan Jr., L.W. Miller, and K.A. Rose. 2001. Analysis of an estuarine striped bass population: Effects of environmental conditions during early life. Estuaries 24:556-574.*

Kimmerer, W., B. Mitchell, and A. Hamilton. 2001. Building models and gathering data: can we do this better? Pp. 305-307 in R.L. Brown (ed.), Contributions to the biology of Central Valley salmonids, Volume 2. California Department of Fish and Game Fish Bulletin 179.

Sommer, T, B. Harrell, M. Nobriga, R. Brown, P. Moyle, W. Kimmerer, and L. Schemel. 2001. California's Yolo Bypass: Evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture. Fisheries 26:6-16

Kimmerer, W.J., W.A. Bennett, and J.R. Burau. 2002. Persistence of tidally-oriented vertical migration by zooplankton in a temperate estuary. Estuaries 25(3):359-371*

Bennett, W. A., W.J. Kimmerer, and J.R. Burau. 2002. Plasticity in vertical migration by native and exotic fishes in a dynamic estuarine low-salinity zone. Limnol. Oceanogr. 47:1496-1507

Kimmerer, W.J. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? Marine Ecology Progress Series 243:39-55.*****

Monismith, S.G., W. Kimmerer, J.R. Burau, and M.T. Stacey. 2002. Structure and flow-induced variability of the subtidal salinity field in northern San Francisco Bay. Journal of Physical Oceanography 32:3003-3019.

Kimmerer, W.J. 2002. Physical, biological, and management responses to variable freshwater flow into the San Francisco estuary. Estuaries.25:1275-1290.*

Kimmerer, W.J. 2004. Open-Water Processes of the San Francisco Estuary: from physical forcing to biological responses. San Francisco Estuary and Watershed Science [online serial]. Vol. 2, Issue 1 (February 2004), Article 1. http://repositories.cdlib.org/jmie/sfews/vol2/iss1/art1

Sommer, T.R., W. Harrell, A. Mueller-Solger, B.Tom, and W. Kimmerer. 2004. Effects of reach-scale hydrologic variation on the biota of channel and floodplain habitats of the Sacramento River, California, USA. Aquatic Conservation: Marine and Freshwater Ecosystems 14:247-261.

Fisher, K. and W. Kimmerer. 2004. Fractal distributions of temperature, salinity and fluorescence in spring 2001-2002 in south San Francisco Bay. In Novak, M.M. (Ed.). Thinking in Patterns: Fractals and Related Phenomena in Nature. World Scientific, Singapore.

Kimmerer, W., D. Murphy, and P. Angermeier. 2005. A landscape-level model of the San Francisco Estuary and its watershed. San Francisco Estuary and Watershed Science [online serial]. Vol. 3, Issue 1 (February 2004), Article 2. http://repositories.cdlib.org/jmie/sfews/vol3/iss1/art2

Kimmerer, W.J. 2005. Long-term changes in apparent uptake of silica in the San Francisco Estuary. Limnology and Oceanography 50: 793-798.*

Choi, K-H., W. Kimmerer, G. Smith, G.M. Ruiz, and K. Lion. 2005. Post-exchange zooplankton in ships ballast water coming to the San Francisco Estuary. Journal of Plankton Research 27: 707-714.

Kimmerer, W.J., M.H. Nicolini, N. Ferm, and C. Peñalva. 2005. Chronic food limitation of egg production in populations of copepods of the genus *Acartia* in the San Francisco Estuary. Estuaries 28: 541–550.*

Gross, E.S., M.L. MacWilliams, and W. Kimmerer. 2006. Simulating Periodic Stratification in San Francisco Bay. Proceedings of the Ninth Estuarine and Coastal Modeling Conference, ASCE, pp. 155-175.

Kimmerer, W.J. 2006. Response of anchovies dampens foodweb responses to an invasive bivalve (*Corbula amurensis*) in the San Francisco Estuary. Marine Ecology Progress Series 324:207-218.*

Bouley, P.B. and W.J. Kimmerer. 2006. Ecology of a highly abundant, introduced cyclopoid copepod in a temperate estuary. Marine Ecology Progress Series 324:219-228.*

Kimmerer, W.J., A.G. Hirst, R.R. Hopcroft, and A.D. McKinnon. 2007. Measurement of juvenile copepod growth rates: corrections, inter-comparisons and recommendations. Marine Ecology Progress Series 336: 187-202.

Sommer, T., C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, B. Herbold, W. Kimmerer, A. Mueller-Solger, M. Nobriga, and K. Souza. 2007. The collapse of pelagic fishes in the upper San Francisco Estuary. Fisheries 32(6): 270-277.

Kimmerer, W.J. and M.L. Nobriga. 2008. Investigating dispersal in the Sacramento-San Joaquin Delta using a particle tracking model. In press, San Francisco Estuary and Watershed Science. [online serial]. Vol. 6, Issue 1 (February 2008), Article 4.

Mcmanus, G. B., J. K. York, and W. J. Kimmerer. 2008. Microzooplankton dynamics in the low salinity zone of the San Francisco Estuary. Verh. Internat. Verein. Limnol. 30: 196-202.

Kimmerer, W. Losses of Sacramento River Chinook salmon and delta smelt to entrainment in water diversions in the Sacramento-San Joaquin Delta. In press, San Francisco Estuary and Watershed Science.

Choi, K-H. and W. Kimmerer. 2008. Mate limitation in an estuarine population of copepods. In Press, Limnology and Oceanography.

Brown, L.R., W.J. Kimmerer, and R.L. Brown. 2008. Managing water to protect fish: a review of California's Environmental Water Account. In press, Environmental Management.

Kondolf, G. M., P. Angermeier, K. Cummins, T. Dunne, M. Healey, W. Kimmerer, P. B. Moyle, D. Murphy, D. Patten, S. Railsback, D. Reed, R. Spies, and R. Twiss. 2008. Projecting cumulative benefits of multiple river restoration projects: An example from the Sacramento-San Joaquin River System in California. In Press, Environ. Manage.

In preparation

Grimaldo, L., W. Kimmerer, and A.R. Stewart. Diets and carbon sources of fishes from open-water, intertidal edge, and SAV habitats in restored freshwater wetlands of the San Francisco Estuary. In preparation for Estuaries and Coasts.

Bills, J., G. Smith, K.-H. Choi, G. Ruiz, and W. Kimmerer. Efficiency of the removal of estuarine zooplankton from ships' ballast tanks by mid-ocean exchange. In preparation for Biological Invasions.

Choi, K.-H. and W. Kimmerer. Mating success and its consequences for population growth of an estuarine copepod. In preparation for Journal of Plankton Research.

Kimmerer, W.J. and R.L. Brown. Winter Chinook salmon in the Central Valley of California: Life history and management. In preparation for San Francisco Estuary and Watershed Science.

Edwards, K.P., K.A. Rose, W.J. Kimmerer, and W.A. Bennett. Individual-based modeling of delta smelt population dynamics in the Upper San Francisco Estuary. 1. Model description and baseline simulations. In preparation for Ecological Modelling.

Kimmerer, W.J., E.S. Gross, and M.L. MacWilliams. Variation of physical habitat for estuarine nekton with freshwater flow in the San Francisco Estuary. In preparation for Estuaries and Coasts.

Gross, E.S., M.L. MacWilliams, and W.J. Kimmerer. Three-Dimensional Modeling of Tidal Hydrodynamics in the San Francisco Estuary. In preparation for San Francisco Estuary and Watershed Science.

* Available in pdf format at http://online.sfsu.edu/~kimmerer/Files/

Selected Presentations

Kimmerer, W.J. 2004. Ecosystem-level changes following foodweb disruption by an introduced clam in the San Francisco Estuary. CALFED Science Conference, Sacramento, October 2004.

Kimmerer, W.J. 2004. Population trends and the influence of restoration actions on winter-run Chinook salmon. Invited, CALFED Science Conference, Sacramento, October 2004.

Kimmerer, W.J. 2004. Assessing the CALFED Bay-Delta Ecosystem Restoration Program: Racing to Catch Up. Invited plenary talk, First National Conference on Ecosystem Restoration, Orlando

Kimmerer, W.J. 2005. The importance of scale and frame of reference in understanding and restoring an estuarine ecosystem. Humboldt Bay Symposium, Arcata, CA, March 2005.

Kimmerer, W.J. 2005. Searching for clues to declines in the pelagic food web of the upper San Francisco Estuary. Invited, State of the Estuary conference, October 2005; Invited, Estuarine Research Federation, October 2005.

Kimmerer, W.J. 2005. Ecosystem-level changes following foodweb disruption by an introduced clam in the northern San Francisco Estuary. Invited, Estuarine Research Federation, October 2005.

Kimmerer, W.J. and J.K. Thompson. 2006. Thresholds and Amplifiers in an Estuarine Ecosystem. Ocean Sciences Meeting (ASLO/AGU), Honolulu, HI**.**

Kimmerer, W.J. Foodweb support for the threatened delta smelt: Subtle interactions may be a cause of the pelagic organism decline. CALFED Science Conference, Sacramento, October 2006.

Kimmerer, W.J. 2005. The importance of scale and frame of reference in understanding and restoring an estuarine ecosystem. Humboldt Bay Symposium, Arcata, CA, March 2005.

Kimmerer, W.J. 2005. Some comments on the Pelagic Organism Decline. California Bay-Delta Authority, August 2005.

Kimmerer, W.J. 2005. Searching for Clues to Declines in the Delta Pelagic Food Web. Invited, State of the Estuary conference, October 2005.

Kimmerer, W.J. 2005. Ecosystem-level changes following foodweb disruption by an introduced clam in the northern San Francisco Estuary. Invited, Estuarine Research Federation, October 2005.

Kimmerer, W.J. 2005. Searching for Clues to Declines in the Pelagic Food Web of the Upper San Francisco Estuary. Invited, Estuarine Research Federation, October 2005; also seminar, U.C. Davis, December 2005.

Kimmerer, W.J. and J.K. Thompson. 2006. Thresholds and Amplifiers in an Estuarine Ecosystem. Ocean Sciences Meeting (ASLO/AGU), Honolulu, HI.

Kimmerer, W.J. 2007. Indirect human impacts on an estuarine foodweb illustrate the false dichotomy of top-down and bottom-up. Fourth Zooplankton Production Symposium, Hiroshima Japan, May 2007.

Go to Main Content

Skip Module Navigation Links

Student Services & Financial Aid | Personal Information

Search Search Go | RETURN TO MENU | SITE MAP | HELP | EXIT

Display Transcript

This is NOT an official transcript. Courses which are in progress may also be included on this transcript.

Institution Credit | Transcript Totals | Courses in Progress

Transcript Data

STUDENT INFORMATION

Birth Date:	Dec 09, 1977
Student Type:	Continuing

Curriculum Information

Current Program

College:	Graduate Studies
Major and Department:	Geography, Design

***Transcript type:STU is NOT Official ***

DEGREES AWARDED

Advanced to Candidacy: Doctor of Philosophy **Degree Date:**

Curriculum Information

Primary Degree

Major: Geography

	Passed	Completed	Attempted	Grade Points	GPA
Institution:	30.000	178.000	30.000	116.40	3.88

INSTITUTION CREDIT -Top-

Fall Quarter 2003

College: Graduate Studies
Major: Geography
Student Type: New
Academic Standing: Good Standing

Subject	Course	Title	Grade	Units	Grade Points	Start and End Dates	R
ECL	200A	Ecol Principles	A	4.000	16.00		
ECL	298	Group Study	S	4.000	0.00		
GEO	200A	Research Trends	S	1.000	0.00		
WFC	120	Biol Cons Fishes	A	3.000	12.00		

Term Totals (Graduate Level - Qtr.)

	Passed	Completed	Attempted	Grade Points	GPA
Current Term:	7.000	12.000	7.000	28.00	4.00
Cumulative:	7.000	12.000	7.000	28.00	4.00

Unofficial Transcript

Winter Quarter 2004

College: Graduate Studies
Major: Geography

Student Type: Continuing
Academic Standing: Good Standing

Subject	Course	Title	Grade	Units	Grade Points	Start and End Dates	R
ECL	205	Community Ecology	W03	0.000	0.00		
GEO	200C	Theory and Practice	A-	4.000	14.80		
GEO	297	Geography Seminar	S	2.000	0.00		
GEO	299	Research	S	6.000	0.00		

Term Totals (Graduate Level - Qtr.)

	Passed	Completed	Attempted	Grade Points	GPA
Current Term:	4.000	12.000	4.000	14.80	3.70
Cumulative:	11.000	24.000	11.000	42.80	3.89

Unofficial Transcript

Spring Quarter 2004

College: Graduate Studies
Major: Geography
Student Type: Continuing
Academic Standing: Good Standing

Subject	Course	Title	Grade	Units	Grade Points	Start and End Dates	R
GEO	200D	Research Methods Geog	A-	4.000	14.80		
GEO	299	Research	S	8.000	0.00		

Term Totals (Graduate Level - Qtr.)

	Passed	Completed	Attempted	Grade Points	GPA
Current Term:	4.000	12.000	4.000	14.80	3.70
Cumulative:	15.000	36.000	15.000	57.60	3.84

Unofficial Transcript

Fall Quarter 2004

College: Graduate Studies
Major: Geography
Student Type: Continuing
Academic Standing: Good Standing

Subject	Course	Title	Grade	Units	Grade Points	Start and End Dates	R
ESP	155	Wetland Ecology	A	4.000	16.00		
GEL	292	River Forum	S	1.000	0.00		
GEO	297	Geography Seminar	S	2.000	0.00		
GEO	299	Research	S	4.000	0.00		
WFC	292	Physiol Fishes Sem	S	1.000	0.00		

Term Totals (Graduate Level - Qtr.)

	Passed	Completed	Attempted	Grade Points	GPA
Current Term:	4.000	12.000	4.000	16.00	4.00
Cumulative:	19.000	48.000	19.000	73.60	3.87

Unofficial Transcript

Winter Quarter 2005

College: Graduate Studies
Major: Geography
Student Type: Continuing
Academic Standing: Good Standing

Subject	Course	Title	Grade	Units	Grade Points	Start and End Dates	R
GEL	292	River Forum	S	1.000	0.00		
GEO	298	Group Study	S	2.000	0.00		
GEO	299	Research	S	9.000	0.00		

WFC	295	Sem Wildl Ecotox	S	3.000	0.00	

Term Totals (Graduate Level - Qtr.)

	Passed	Completed	Attempted	Grade Points	GPA
Current Term:	0.000	15.000	0.000	0.00	0.00
Cumulative:	19.000	63.000	19.000	73.60	3.87

Unofficial Transcript

Spring Quarter 2005

College: Graduate Studies
Major: Geography
Student Type: Continuing
Academic Standing: Good Standing

Subject	Course	Title	Grade	Units	Grade Points	Start and End Dates	R
ECL	214	Marine Ecology	A	3.000	12.00		
GEL	292	River Forum	S	1.000	0.00		
GEO	298	Group Study	S	2.000	0.00		
GEO	299	Research	S	2.000	0.00		
WFC	157	Coastal Ecosystems	A+	4.000	16.00		

Term Totals (Graduate Level - Qtr.)

	Passed	Completed	Attempted	Grade Points	GPA
Current Term:	7.000	12.000	7.000	28.00	4.00
Cumulative:	26.000	75.000	26.000	101.60	3.90

Unofficial Transcript

Fall Quarter 2005

College: Graduate Studies
Major: Geography
Student Type: Continuing

Academic Standing: Good Standing

Subject	Course	Title	Grade	Units	Grade Points	Start and End Dates	R
AGR	206	Multivar Syst & Modeling	A-	4.000	14.80		
GEO	299	Research	S	12.000	0.00		

Term Totals (Graduate Level - Qtr.)

	Passed	Completed	Attempted	Grade Points	GPA
Current Term:	4.000	16.000	4.000	14.80	3.70
Cumulative:	30.000	91.000	30.000	116.40	3.88

Unofficial Transcript

Winter Quarter 2006

College: Graduate Studies
Major: Geography
Student Type: Continuing
Academic Standing: Good Standing

Subject	Course	Title	Grade	Units	Grade Points	Start and End Dates	R
GEO	299	Research	S	12.000	0.00		

Term Totals (Graduate Level - Qtr.)

	Passed	Completed	Attempted	Grade Points	GPA
Current Term:	0.000	12.000	0.000	0.00	0.00
Cumulative:	30.000	103.000	30.000	116.40	3.88

Unofficial Transcript

Spring Quarter 2006

College: Graduate Studies
Major: Geography

Student Type: Continuing
Academic Standing: Good Standing

Subject	Course	Title	Grade	Units	Grade Points	Start and End Dates	R
APC	299	Research	S	3.000	0.00		
GEO	299	Research	S	12.000	0.00		

Term Totals (Graduate Level - Qtr.)

	Passed	Completed	Attempted	Grade Points	GPA
Current Term:	0.000	15.000	0.000	0.00	0.00
Cumulative:	30.000	118.000	30.000	116.40	3.88

Unofficial Transcript

Fall Quarter 2006

College: Graduate Studies
Major: Geography
Student Type: Continuing
Academic Standing: Good Standing

Subject	Course	Title	Grade	Units	Grade Points	Start and End Dates	R
APC	299	Research	S	6.000	0.00		
GEO	299	Research	S	6.000	0.00		

Term Totals (Graduate Level - Qtr.)

	Passed	Completed	Attempted	Grade Points	GPA
Current Term:	0.000	12.000	0.000	0.00	0.00
Cumulative:	30.000	130.000	30.000	116.40	3.88

Unofficial Transcript

Winter Quarter 2007

College: Graduate Studies
Major: Geography
Student Type: Continuing
Academic Standing: Good Standing

Subject	Course	Title	Grade	Units	Grade Points	Start and End Dates	R
GEO	299	Research	S	12.000	0.00		

Term Totals (Graduate Level - Qtr.)

	Passed	Completed	Attempted	Grade Points	GPA
Current Term:	0.000	12.000	0.000	0.00	0.00
Cumulative:	30.000	142.000	30.000	116.40	3.88

Unofficial Transcript

Spring Quarter 2007

College: Graduate Studies
Major: Geography
Student Type: Continuing
Academic Standing: Good Standing

Subject	Course	Title	Grade	Units	Grade Points	Start and End Dates	R
APC	299	Research	S	12.000	0.00		

Term Totals (Graduate Level - Qtr.)

	Passed	Completed	Attempted	Grade Points	GPA
Current Term:	0.000	12.000	0.000	0.00	0.00
Cumulative:	30.000	154.000	30.000	116.40	3.88

Unofficial Transcript

Fall Quarter 2007

College: Graduate Studies
Major: Geography
Student Type: Continuing
Academic Standing: Good Standing

Subject	Course	Title	Grade	Units	Grade Points	Start and End Dates	R
APC	299	Research	S	12.000	0.00		
APC	299	Research	W10	0.000	0.00		

Term Totals (Graduate Level - Qtr.)

	Passed	Completed	Attempted	Grade Points	GPA
Current Term:	0.000	12.000	0.000	0.00	0.00
Cumulative:	30.000	166.000	30.000	116.40	3.88

Unofficial Transcript

Winter Quarter 2008

College: Graduate Studies
Major: Geography
Student Type: Continuing
Academic Standing: Good Standing

Subject	Course	Title	Grade	Units	Grade Points	Start and End Dates	R
APC	299	Research	S	12.000	0.00		

Term Totals (Graduate Level - Qtr.)

	Passed	Completed	Attempted	Grade Points	GPA
Current Term:	0.000	12.000	0.000	0.00	0.00
Cumulative:	30.000	178.000	30.000	116.40	3.88

Unofficial Transcript

TRANSCRIPT TOTALS (GRADUATE LEVEL - QTR.) -Top-

Level Comments: ***Student cancelled from F08, owes S08 fees***

	Passed	Completed	Attempted	Grade Points	GPA
Total UC Davis:	30.000	178.000	30.000	116.40	3.88
Total UC:	30.000	178.000	30.000	116.40	3.88
Total Transfer:	0.000	0.000			
Overall:	30.000	178.000			

Unofficial Transcript

COURSES IN PROGRESS -Top-

Spring Quarter 2008

College: Graduate Studies
Major: Geography
Student Type: Continuing

Subject	Course	Title	Units	Start and End Dates
APC	299	Research	12.000	

Skip to top of page

Skip Academic Transcript Links

[Overall Financial Aid Status | Financial Aid Eligibility Menu]

Release: 7.2

University of California, Santa Barbara
Office of the Registrar, Santa Barbara, CA 93106-2015

PRINTED: 12/02/02 PAGE: 3

OFFICIAL TRANSCRIPT

STUDENT NAME: KEMAL ALI GER PERM NUMBER: 398077

COURSE		TITLE	GRADE	COMPLETE UNITS	GPA UNITS	GRADE POINTS	GPA
1999 Spring Quarter Senior							
EEMB	109	VERT. PALEONTOLOGY	B+	4.0	4.0	13.20	
EEMB	199	INDEPENDENT STUDIES	A	3.0	3.0	12.00	
ESM	201	ECOLOGICAL PRINCIPL	A	4.0	4.0	16.00	
GEOL	120	FIELD PALEOBIOLOGY	P	1.0	0.0	0.00	
		Quarterly Total:		12.0	11.0	41.20	3.74
THRU S99		Total:		134.0	118.0	432.60	3.66
2000 Fall Quarter							
Admitted into the Master of Env. Science and Mgmnt. Program in Environmental Science and Management							
Admitted into the Master of Env. Science and Mgmnt. Program in Environmental Science and Management							
EEMB	243	BIOLOGICAL OCEANOG.	A	3.0	3.0	12.00	
ESM	200	ENV CASE STUDIES	S	1.0	0.0	0.00	
ESM	203	EARTH SYSTEM SCI	A	4.0	4.0	16.00	
ESM	207	ENV. LAW & POLICY	B+	4.0	4.0	13.20	
ESM	210	MGMT BUSINESS ORGS	A	4.0	4.0	16.00	
		Graduate Total:		16.0	15.0	57.20	3.81
THRU F00		Graduate Total:		16.0	15.0	57.20	3.81
2001 Winter Quarter							
ESM	202	ENV BIOGEOCHEM	A	4.0	4.0	16.00	
ESM	204	ECON ENV MNGMNT	A	4.0	4.0	16.00	
ESM	206	DATA ANALYSIS	A	4.0	4.0	16.00	
ESM	246	INTL ENV ECON	A+	4.0	4.0	16.00	
		Graduate Total:		16.0	16.0	64.00	4.00
THRU W01		Graduate Total:		32.0	31.0	121.20	3.90
2001 Spring Quarter							
ESM	234	RIVER SYSTEMS	A	4.0	4.0	16.00	
ESM	263	GEOG. INFO. SYSTEMS	B+	4.0	4.0	13.20	
ESM	297	ADV TOPICS ENV POL	A	2.0	2.0	8.00	
ESM	401A	GROUP PROJECT - A	A-	4.0	4.0	14.80	
ESM	595I	GROUP STUDIES	S	2.0	0.0	0.00	
		Graduate Total:		16.0	14.0	52.00	3.71
THRU S01		Graduate Total:		48.0	45.0	173.20	3.84
2001 Fall Quarter							
ESM	215	LANDSCAPE ECOLOGY	A-	4.0	4.0	14.80	
ESM	243	POLICY ANALYSIS	A-	4.0	4.0	14.80	
ESM	401B	GROUP PROJECT - B	A-	4.0	4.0	14.80	
ESM	410	INTERN PRACTICUM	S	1.0	0.0	0.00	
		Graduate Total:		13.0	12.0	44.40	3.70
THRU F01		Graduate Total:		61.0	57.0	217.60	3.81

CONTINUED TO PAGE 4

ISSUED TO:

SILVIA CASTILLO HILLYER
UC DAVIS
GRAD GROUP IN ECOLOGY, 2148 WICKSON
ONE SHIELDS AVE
DAVIS CA 95616

To be valid, this POSTALBOXX™ field must display a colored background.

Beverly Q. Lewis
Registrar

This officially sealed and signed transcript is printed on blue security paper with the signature printed in white. A raised seal is not required. When photocopied, a security statement containing the name of the institution will appear. A BLACK ON WHITE OR A COLOR COPY SHOULD NOT BE ACCEPTED.

University of California, Santa Barbara
Office of the Registrar, Santa Barbara, CA 93106-2015

PRINTED: 12/02/02 PAGE: 4

OFFICIAL TRANSCRIPT

STUDENT NAME: KEMAL ALI GER PERM NUMBER: 398077

COURSE	TITLE	GRADE	COMPLETE UNITS	GPA UNITS	GRADE POINTS	GPA
2002 Winter Quarter						
ESM 257	MARINE MGT PLANNING	A-	4.0	4.0	14.80	
ESM 282	INDUSTRIAL ECOLOGY	A	4.0	4.0	16.00	
ESM 401C	GROUP PROJECT - C	A-	4.0	4.0	14.80	
	Graduate Total:		12.0	12.0	45.60	3.80
THRU W02	Graduate Total:		73.0	69.0	263.20	3.81
2002 Spring Quarter						
ESM 235	WATERSHED ANALYSIS	A+	4.0	4.0	16.00	
ESM 259	INTEGR COASTAL MGMT	A-	4.0	4.0	14.80	
	Graduate Total:		8.0	8.0	30.80	3.85
THRU S02	Graduate Total:		81.0	77.0	294.00	3.81
UC Credit Undergraduate Total:			134.0	118.0	432.60	3.66
TRANSFER Credit Undergraduate Total:			51.0			
ALL Credit Undergraduate Total:			185.0			
UC Credit Graduate Total:			81.0	77.0	294.00	3.81

SCHOOL	ATTENDED FROM	ATTENDED THRU	DEGREE	DEGREE TERM	ACCEPTED UNITS
HANFORD JOINT UNION HS WEST		Spring 95	HS	Spring 95	
TOEFL EXAMINATION		Fall 95			
HACETTEPE UNIVERSITY	Fall 95	Spring 96			51.0

** END OF RECORD **

THE REGISTRAR'S WHITE SIGNATURE IS IMPOSED UPON A LIGHT BLUE INSTITUTIONAL SEAL.
THE DOCUMENT SHOULD BE REJECTED IF EITHER IS DISTORTED.

ISSUED TO:

SILVIA CASTILLO HILLYER
UC DAVIS
GRAD GROUP IN ECOLOGY, 2148 WICKSON
ONE SHIELDS AVE
DAVIS CA 95616

To be valid, this POSTALBOXX™ field must display a colored background.

Beverly Q. Lewis
Registrar

This officially sealed and signed transcript is printed on blue security paper with the signature printed in white. A raised seal is not required. When photocopied, a security statement containing the name of the institution will appear. A BLACK ON WHITE OR A COLOR COPY SHOULD NOT BE ACCEPTED.

UNIVERSITY OF CALIFORNIA, DAVIS

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO • SAN FRANCISCO SANTA BARBARA • SANTA CRUZ

SCHOOL OF VETERINARY MEDICINE
ANATOMY, PHYSIOLOGY AND CELL BIOLOGY
UNIVERSITY OF CALIFORNIA
(530) 752-1174
FAX (530) 752-7690

ONE SHIELDS AVENUE
DAVIS, CALIFORNIA 95616-8734

June 5th 2008

To Whom It May Concern:

I am very pleased to write this letter in support of Mr. Kemal Ali Ger for the CALFED Science Fellows program. I have known Ali for the past 2.5 years, during which I had many opportunities to observe his skills and personality. We have worked closely, planning, debating, and executing experiments. Ali is a neat and organized person who carefully plans the use of his time and works very efficiently and independently. He has achieved excellence in the academic work (GPA 3.7) and will be graduating from my lab in December 2008. His eagerness to learn is apparent in his exceptional performance in graduate courses, laboratory experiments, and the development of new methods.

The Delta *Microcystis* bloom first appeared in the Sacramento-San Joaquin River Delta in the early 1990's, and contains microcystins that are potent liver toxins in wildlife and humans. It is anticipated that *Microcystis* blooms will increase in duration and biomass as a result of climate change and increased water use in California. Little is known about the spatial and temporal variability of *Microcystis* biomass and toxicity and its impact on zooplankton production in the Delta.

Ali's dissertation work is not only timely from a local management perspective but also in the larger study of harmful algal blooms and toxins, a recently expanding topic of concern globally. His research will focus on the interactions between toxic *Microcystis* and zooplankton. His research findings combining laboratory exposure tests with field surveys to address fundamental questions of *Microcystis*-copepod interactions will provide essential information on novel approaches to *Microcystis* toxicity which is currently lacking.

He has extensive experience with spawning and culturing of *Eurytemora affinis* and *Pseudodiaptomus forbesi* in my laboratory. He is also very creative, independent, and persistent, as he has developed on his own, novel methods to successfully culture the copepods needed for this study, which is an accomplishment in itself. In addition, Ali has been trained in designing and performing acute and chronic toxicity testing. I truly believe that his research will add significantly to our understanding of the mechanism between *Microcystis* exposure and biological effects on copepods, which will provide critical information on the fate and toxicity of *Microcystis* bloom in the Delta. I have full confidence that he will successfully complete his project if funded. Furthermore, I will be happy to provide you with copepods or to help with the qPCR study as needed. I look forward to collaborating with you on this project.

Ali's solid academic performance and productive research provide strong indication of future success as a scientist and thus I highly recommend Ali for this Fellowship.

Sincerely,

Swee Teh, Ph.D
VM: Anatomy, Physiology, and Cell Biology, School of Veterinary Medicine
1321 Haring Hall, One Shields Avenue, UC-Davis, California 95616
Tel: (530) 754-8183, Fax: (530) 752-7690, e-mail: sjteh@ucdavis.edu

UNIVERSITY OF CALIFORNIA, DAVIS

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO • SAN FRANCISCO • SANTA BARBARA • SANTA CRUZ

DEPARTMENT OF ENVIRONMENTAL SCIENCE AND POLICY

ONE SHIELDS AVENUE
DAVIS, CALIFORNIA 95616-8576

June 4, 2008

It is my pleasure to write a letter of recommendation for Mr. Kemal Ali Ger to support his application for a CalFed Postdoctoral Fellowship. I have known Ali for over four years. I met him when he finished his degree at UC Santa Barbara and discussed the possibility of becoming my PhD student. I decided to accept him for the same reasons that I now consider him to be an ideal candidate for this funding: as a student he has shown great potential to carry out independent, influential, and publishable research in his areas of interest. His proposed research study was conceived and written entirely by Ali; I provided only suggestions for literature searches in its preparation. He is truly an independent thinker with an original approach to any task he undertakes.

Ali has been a quality student, and his educational and cultural backgrounds provide him with unique capabilities. Although he is a Turkish citizen, he spent his undergraduate and Masters years in the US, where he attended UC Santa Barbara. He graduated with an outstanding academic record and a wealth of experience. His undergraduate degree is in Ecology and Evolution with a cumulative GPA of 3.75, and his Masters in Coastal Management with a GPA of 3.81. Beyond getting good grades, he truly enjoys intellectual and practical applications of his interests. Ali wants to be involved with research that highlights the connections between anthropogenic activities and processes in coastal and estuary ecosystems. To this end, he has worked at different organizations to learn more about various aspects of aquatic resource management and is familiar with the distinct political cultures and context of academia, public agencies, and non-profits.

During the summers of 2003-2006, he was part of a four-person crew that operated the UC Davis Limnological Research Laboratory at Castle Lake. Last summer was one of the best years in terms of both quantity and quality of research at Castle Lake in recent years, and without Ali it would not have been so. He assumed a leadership position at the lake while continuing his research on cyanobacterial toxicity in the food chain of the Bay-Delta system. This work is in the very final stages of completion for his PhD which will be finished at just the appropriate time to take on the postdoctoral work he has outlined. While working at Castle Lake he became familiar with a variety of standard limnological sampling techniques, how to set up and design experiments, and how to continue when unexpected events require alteration of design. Additionally, he partnered with UCDMC Professor Robert Derlet on a new project looking at bacterial abundance and human use in lakes of the high Sierra Nevada. He presented the findings of this study at the International Society of Limnology (SIL) Congress in Finland in 2004. I attended his presentation and found it to be very professional, enthusiastic, and well-received by a critical scientific audience. He is a natural to become a Research and Teaching Professor at a University.

Ali was also the Teaching Assistant for my Limnology laboratory and field course (ESP 151L) in spring quarter 2004, where he became even more familiar with the intricacies of field and laboratory sampling, and was able to overcome the usual unexpected field course impediments with ease.

Ali became involved in the local, emerging, and important issue of algal blooms and eutrophication; specifically, the threatening blooms of the cyanobacteria *Microcystis* in the Sacramento-San Joaquin River Delta for his PhD thesis. His proposal was focused, with an up-to-date methodology that addresses a very pertinent research question: what is causing the blooms of *Microcystis*? He completed an extensive literature review, wrote a CalFed proposal to support the fieldwork, and is now experienced with the sampling requirements.

The proposed postdoctoral work is an excellent follow-up to his thesis work on *Microcystis* toxicity in the food chain and expands the work to include a more holistic view of the Bay-Delta food chain dynamics. In short, the proposed postdoctoral research is realistic in its scope and in its timeline. The Delta is a region of intense agricultural activity, water management, and a source of drinking water to millions of Californians. The onset of harmful algal blooms in this region, which are also studied for other important aspects including wetland restoration, requires strict monitoring and study, both of which Ali has undertaken. Ali's motivation to complete his degree on schedule has been impressive at a time when some graduate students settle into graduate work as a career. Ali is fully capable of successfully completing a successful and important postdoctoral program and is a very deserving candidate for CalFed support. Ali's proposal fits nicely within the domain of the research requirements to solve Bay-Delta food chain problems with immediate practical significance. In summary, I strongly urge you to consider Ali Ger favorably for postdoctoral support. He is an outstanding candidate with a well designed and justified research proposal.

Sincerely,

Charles R. Goldman

Distinguished Professor of Limnology

Director, Tahoe Research Group

Laureate, Albert Einstein World Award of Science

Anke Mueller-Solger, Ph.D.
Staff Environmental Scientist
California Department of Water Resources, Division of Environmental Services
901 P Street, PO Box 942836, Sacramento, CA 95814-6424
Office: (916) 651-0179; Fax: (916) 651-0209; amueller@water.ca.gov

05-05-2008

Support letter for 2008 CALFED Science Fellows Proposal by **Kemal Ali Ger**

To Whom it May Concern:

I am writing to offer my enthusiastic support for a proposal to the CALFED Science Fellows Program by **Kemal Ali Ger.**

I am a Staff Environmental Scientist with the California Department of Water Resources and was previously a research scientist at UC Davis. In these capacities, I have been and continue to be intensely involved with a number of research projects funded by the CALFED program as well as with monitoring and research programs conducted in the upper San Francisco Estuary (SFE) by the Bay-Delta Interagency Ecological Program (IEP). In addition, I have led various planning aspects of CALFED Science Conferences, including serving as Conference Co-Chair for the 2006 and 2008 conferences, and I have participated in many CALFED and IEP workshops. I am also the current chair of the IEP Pelagic Organism Declines (POD) Management Team.

Results of studies coordinated by the POD team point to changes in trophic structure and species composition and increasing toxicity as possible mechanisms leading to the recent precipitous declines of several important fish species in the SFE. Of particular concern is the rise in harmful algal blooms, especially the steady increase in spatial extent and intensity of blooms of *Microcystis aeruginosa* in the Delta and into Suisun Bay over the last decade. Another alarming trend is the rise in small and presumably less nutritious zooplankton species such as *Limnoithona tertraspina*. Ongoing CALFED and POD work is focusing on the dynamics, toxicity, and nutritional quality of *Microcystis* blooms in the Delta. Some of this work has been carried out by K. A. Ger himself as his dissertation project, and his results have already been very helpful in assessing the role of *Microcystis* in the POD. The new study proposed by K.A. Ger would expand his previous, more narrow work on nutritional quality and toxicity of *Microcystis* for two SFE copepod species to include more copepod species, new cutting-edge methods, and a focus on *Microcystis* impacts on the food web. I am particularly excited about the proposed investigations of connections between increasing prevalence of *Microcystis* and shifts in zooplankton community composition and trophic pathways. So far, reasons for the observed dramatic community shifts remain largely unclear. The proposed research is likely to provide an important piece in the POD puzzle and shed light on the hypothesis that *Microcystis* is not only a nuisance species, but also a veritable "ecosystem engineer." Further, I am also highly enthusiastic about the proposed combination of cutting-edge qPCR techniques with traditional laboratory and field incubation experiments and field sampling. These types of techniques could soon become invaluable in environmental monitoring and research, and the project proposed by K. A. Ger would serve as an important test of this emerging technology for use in research, monitoring, and adaptive management in the SFE.

K. A. Ger proposes to utilize a combination of sophisticated novel and well established monitoring and experimental laboratory and field methods to characterize zooplankton ingestion of *Microcystis*, and *Microcystis* effects on the food web. I believe that his proposed work will be an excellent complement to ongoing research and monitoring work. Based on his previous research experience and education, K. A. Ger is well prepared to carry out the proposed project, but also likely to gain a large amount of new research experience, especially about the development and utilization of qPCR techniques in ecological research and monitoring applications. I believe that K. A. Ger's proposed research project is clearly suitable for an academic postdoctoral project under the guidance of experienced research and community mentors. I would be happy to serve as a State agency community mentor for this project and assure close connectedness to SFE issues, State agencies and resources, CALFED, and the IEP.

Sincerely, Anke Mueller-Solger, CA DWR, Sacramento